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The Use of a Mobile telephone and an interface for assisting handicapped.

By
Ali Matrouk Aldallaen

Supervisor
Prof. Mustafa Muheilan

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Dedication

"To my mother, family, brother and all friends in all places in the world"

Ali Matrouk Al-Dallaen

Acknowledgments

I would like to thank my supervisor, Professor. Mustafa Muheilan for his support and encouragement, for helping me throughout my research project. I thank my mother, family, and brothers for their support and their prayers; finally my thanks to all my friends.

Ali Matrouk Al-Dallaen

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List of abbreviations

2G	Second Generation
ASC	Asynchronous/Synchronous
AT	Attention
CBCH	Cell Broadcast Channel
CS	Coding Scheme
CTS	Clear To Send
DC	Direct Current
DCD	Data Carrier Detector
DCE	Data Communication Equipment
DCS	Digital Cellular Service
DL	Down Link
DSR	Data Set Ready
DTE	Data Terminal Equipment
DTMF	Dual Tone Multi Frequency
DTR	Data Terminal Read
EDGE	Enhanced Data GSM Environment
EEADR	EEPROM Address
EEDATA	EEPROM Data
EIA	Electronic Industries Association
FDMA	Frequency Division Multiple Access
GPR	General Purpose Register
GPRS	General Packet Radio Service
GSM	Global System for Mobile communications
HACS	Home Appliance Control System
IC	Integrated Circuit
ID	Identifier
IMT2000	International Mobile Communication 2000
ISDN	Integrated Service Digital Network
ISDN	Integrated Service Digital Network
ISMI	International Mobile Subscriber Identities
LCD	Liquid Crystal Display
MCU	Microcontroller Unit
ME	Mobile Equipment
MoU	Memorandum of Understanding
MS	Mobile Station
MT	Mobile Termination
NAMPS	Narrowband Advanced Mobile Phone Service
NMTS	Narrowband Mobile Telephony

PBCCH	Packet Broadcast Control Channel
PCCCH	Packet Common Control Channel
PCL	Program Counter Low Byte
PCLATH	Program Counter Latch High
PCM	Pulse Code Modulation
PCM	Pulse Code Modulation
PIC	Peripheral Interface Controller
PLMN	Public Land Mobile Network
PV	Photovoltaic
RF	Radio Frequency
RTS	Request To Send
SIM	Subscriber Identity Module
SMS	Short Messages
TACS	Total Access Communication System
TDMA	Time Division Multiple Access
TM1	Teltonika Module1
TTED	Tele Terminal Equipment Directives
TTL	Transistor -Transistor Logic
UART	Universal Asynchrony Receive Transmit
UL	Up Link
UPS	Uninterruptable Power Supply
VBAT	Battery Voltage (Voltage from Battery)
VT	Valid Transmission
WCDMA	Wideband Code Division Multiple Access

Abstract

The Use of a Mobile telephone and an interface for assisting handicapped

Ali Matrouk Al-Dallaen

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In modern days, various remote control systems are implemented to simplify our life especially for handicapped people who cannot move to switch on or off their home devices such as switching light on and off, open garage door or start some motors within their houses, using this design these people can control these devices remotely from anywhere on our planet. In this project, a great remote control system has been designed and implemented to control three home devices from any place in the world by just sending small messages using GSM network, or using Bluetooth technology being near to the devices. So being near to these controlled devices and using Bluetooth technology a person can control them without paying money to the GSM network provider, in both remote control systems feedback SMSs are sent to the user indicating the state of the controlled device using the existing GSM network.

الملخص

استعمال الهاتف الخلوي لمساعدة ذوي الاحتياجات الخاصة

علي متروك الضلاعين

جامعة مؤتة، 2013

في هذه الأيام، هناك أنظمة تحكم مختلفة تطبق من أجل تسهيل الحياة اليومية خاصة ذوي الاحتياجات الخاصة، فبإمكانهم أن يتحكموا باجهزة المنزل عن بعد ومن أي مكان فوق كوكبنا، وفي هذا المشروع تم تصميم وتطبيق نظام تحكم عن بعد ليمكن هؤلاء الناس من تشغيل وإطفاء ثلاثة أجهزة منزلية خدماتية بواسطة ارسال رسائل تحكمية نصية صغيرة عبر الشبكات الخلوية المتاحة (GSM) أو بواسطة استعمال تقنية Bluetooth عند التواجد بالقرب من النظام.

وعند استعمال كلا النظامين هنالك رسالة راجعة تبين حالة الاجهزة المتحكم بها يتم استقبالها بواسطة الشبكات الخلوية المتاحة (GSM) كرسالة نصية SMS.

Chapter one
Literature review

1.1 Introductions

Nowadays, Remote control system became a great demand in all over the world, one of these systems is to use a mobile station to remotely control devices using GSM when a user is located at long distance from the controlled devices, and using Bluetooth technology when he is near to these devices.

If a simple mobile phone takes the responsibility to control home devices then the control is reachable from almost everywhere .This sort of high end technology is supposed to facilitate the different life easing utilities to a new age.

Mobile telephony offers a wide range of communication services like voice and data transfer through SMS, Bluetooth and other enhanced data transfer protocols like GPRS, in this thesis we produce two ways to control the home devices, the first one is sending SMSs using existing GSM network from anywhere in the world, and the second one using Bluetooth technology when the mobile station is near to the controlled devices, and in both ways, a feedback message is sent to the user by GSM network indicating the device status. In this system a delay time taken by the system from the moment the control message is send to the moment the feedback status message is received is calculated.

In this design, remote controlling has been established for three devices as shown in Figure.1: Lighting, pump and garage door.

Amit Chnhan, Reecha Ranjan Singth developed a system that assists a user to remotely control multiple home electrical devices using a mobile cellular phone. this system is powerful that offers this service at any time and from anywhere via GSM network. In the proposed project a microcontroller-based control module which receives instructions and commands from a mobile phone was implemented. The system will activate the appropriate devices and send the device status back to the user phone. Only GSM was used as wireless technology, wired connections were used from the microcontroller to the controlled devices, in our design there were no wired connections used; all devices were controlled by pure wireless technologies.[1]

R.Ramani et al. developed a project of a remote control and monitoring system for a water tank level, this system monitors the water level inside a tank and in case of decreasing the water level below predefined value or exceeding some other value the owner will be informed by receiving a mobile call using GSM network. The user can immediately switch on or switch off

the pump motor by sending a control SMS message using GSM network. In this scenario the system will keep the pump from getting air locked or burning out due to dry running. The system is simple, reliable, portable and affordable. In the proposed design , a list of hardware components are used like: GSM modem, microcontroller, level sensors and control relays. [2]

In the paper issued by Mohammad Helmy Abdlwahab a remote control system using GSM network was developed to reduce power wastage by remotely controlling the home appliances by sending Control SMS messages. This system was designed to receive from mobile phone short messages to switch light on and switch light off, the design was integrated with a microcontroller and GSM interface module using assembly language. The system is activated upon receiving control SMS message and outputs the appropriate signals to switch the home appliance on and off according to the user order. [3]

G.raghavendran represented in his paper issued in 2011 a secure, low cost, auto configurable remote control system for home automation. The design represented in the paper has achieved the target to control home devices remotely using SMS-based system satisfying user needs and requirements, so the required goals and objectives of HACS (Home Appliances Control System)have been achieved and the basic levels of home appliance control and remote monitoring have been implemented. The paper show that the system is extensible and more levels can be further developed.[4]

In the paper issued by R.Chutia, D.Sonoeal and S.Sharmaa remote control system was developed for controlling the home appliance using mobile handset through GSM technology. The system allows the user to monitor and control his house devices from any place via his mobile station by sending commands in the form of SMS messages and receiving feedback SMS indicating the appliances status as well, this system provided ideal solution to the problems caused in situation when a wired connection between a remote device and the control unit might not be feasible. [5]

Tuljapa M Ladwa, Sanjay M Ladwa, R Sudher shanKarthik, AlokRanjan Dhara and NayanDalie proposed a method to control a demostic system using a mobile phone, the paper proposed uses the DTMF (Dual Tone Multi Frequency) generated by pressing a keypad button of the mobile phone by the user, the mobile phone user controls the system by sending the DTMF tones to the access point. This proposed principle can be extended to various applications, DTMF signals can be transmitted over a radio to switch on or switch off home appliances. This system is implemented in 2G mobile communication network. [6].

Sagarika Pal, Nilaldris. Tripalthy represented in their paper the use of DTMF technology to control the position of the shaft of the stepper motor at a desired angle which in turn may be used in different a applications areas. The system developed in this paper is simple, rugged and cost effective. its experimental results shows that one step angle resolution has been achieved the range 3.5 degrees and 24 degrees. also other angular position beyond 24 can be achieved pressing a combinations of two or more keys on the keypad of user mobile phone[7].

V. Bhaskar & T. Gowrie Manohar presented a project of remote control system which can control up to eight devices by sending control SMS messages from a mobile phone, the system switches on and switches off devices without using wired connections to that place of control. A GSM was implemented to receive SMS messages from the user mobile cell phone, then the control signal is extracted from the message and passed to the microcontroller. A PC connected to the microcontroller using RS232 interface is used for monitoring and transmission of the control signals to the modem.AT commands were used for controlling the functionality of the modem, the system is capable of controlling the motor by receiving control message from an authorized mobile phone number.[8]

Sanda Win, Tin Shein and Khin Maung Latta developed a project that controls small robot to move with various speeds and directions, its movement can be controlled by remote control from a distance of fifteen feet. The robot is able to move forward and reverse with various speeds and it can rotate to the left and to the right of up to twenty degrees. It is constructed by using a DC motor and the control software is written by assembly language and preinstalled in a microcontroller. According to the test result, the robot received the control signal and work precisely as instructed. [9].

Er.Swanpnil demonstrated a method which enables users to control home devices remotely using a mobile phone, in this project the home devices are controlled by a mobile phone that makes a call to the other mobile phone attached to the control box which is connected to the controlled devices, but when a person is present at home, he can just press key from his mobile phone keypad then a tone consisting of two frequencies is sent and decoded by DTMF decoder where it is processed and sent to the microcontroller and then, the microcontroller sends the corresponding signals to activate the corresponding devices. [10]

Adamu Murtala Zungeri,Ufaruna Victoria Edu and Ambafi James made a research which focuses on controlling of home appliances remotely when a user is away from his house, the system depends at sending short messages and uses wireless technology to revolutionize the standards of living. the

research is divided into two sections: the hardware and the software, the hardware sections consists of: GSM modem module, the control module, the appliance module, the LCD (Liquid Crystal Display) and the power supply. The GSM modem receives the sent control message, it then forward it to the microcontroller where it is decoded and the microcontroller switches on or off the appropriate device. [11]

Purmnima, S.R.N Reddy developed a project of an automatic irrigation system based on wireless sensors with GSM-Bluetooth technology. this system has simple features designed with the objective of low cost and effective with less power consumption using sensors for remote monitoring and controlling devices which are controlled via SMS using a GSM module. Bluetooth module is also interfaced with the main controller chip. This Bluetooth is used when the application is in limited range of few meters, the system gives an alarm about abnormal conditions like less moisture content and temperature rise via SMS using GSM module or by Bluetooth module.[12]

The paper issued by Roshan Ghosh suggests a method for control using the DTMF tone generated when the user pushes mobile phone keypad buttons or when connected to a remote mobile system. This DTMF based controller is used to control the operation of multiple relays and also for the purpose of efficiency improvement of a PV (Photovoltic) cell by regulating the open circuit voltage of the cell. Method proposed here uses the DTMF (Duel Tone Multi Frequency) when keypad button of mobile phone is pressed by the user. The mobile phone user controls the system by sending DTMF tone to the system. [13].

In this project, different design has been designed and implemented; the system uses three wireless technologies: GSM, Bluetooth and RF. So no wired connections were used absolutely, this gives the system more expandability in the future, so any equipment can be added simply by increasing daughter boards, the system is portable, this means that the control board and daughter boards can be relocated where it is needed within the range of Bluetooth and RF technologies.

1.2 Aims and objectives

The main aim and objective of this worthy project is to build and implement complete remote control system for assisting handicapped people to remotely control and monitor their home appliances using mobile telephone from anywhere in the world using existing GSM network or Bluetooth being near to the home, this requires to develop an a suitable interface which

consists of several hardware components and a suitable software to make these components deal with each other in a proper way.

1.3 Main block diagram.

In this thesis a complete control system was designed and implemented which can assist handicapped people to remotely control the home equipment using GSM system by sending SMS messages from anywhere in the world or a DTMF technology over Bluetooth wireless technology being near to the controlled equipment, there are no wires run from the control board to any of the home equipment, but instead an RF wireless technology is used. This is shown in the following block diagram of Figure.1

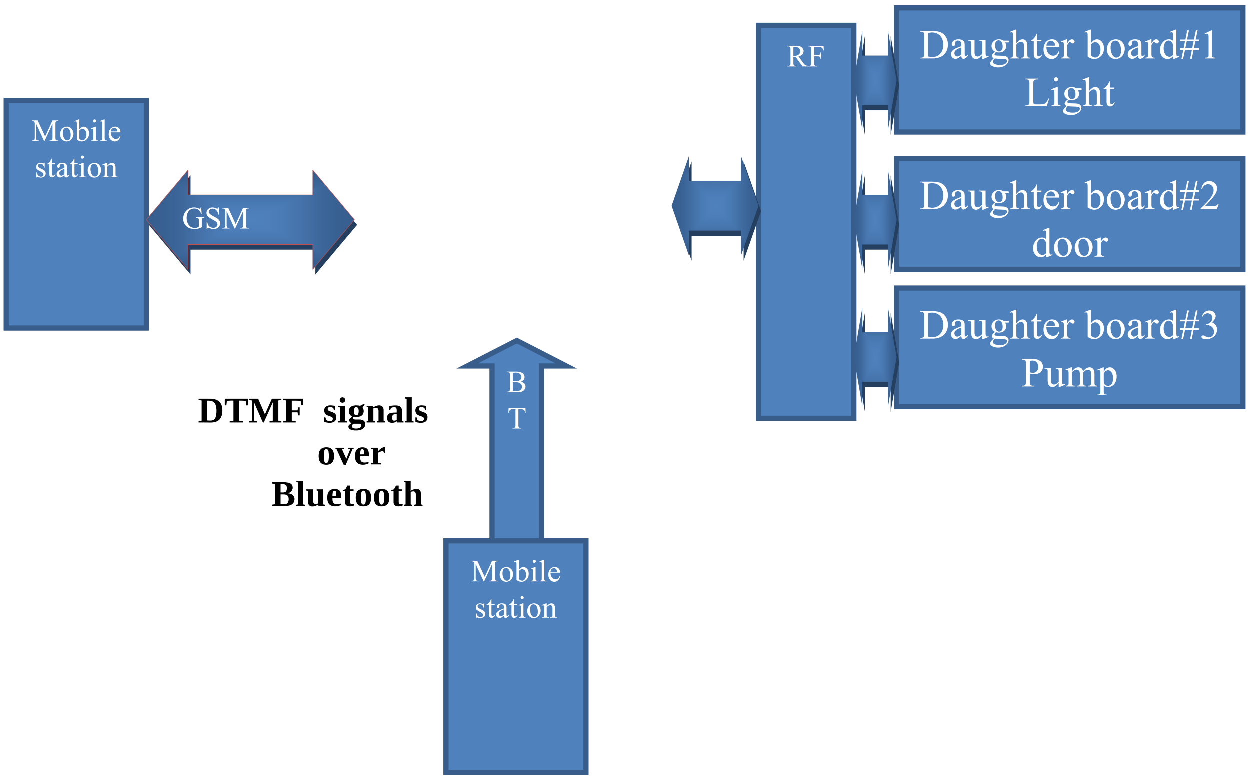


Fig (1)
Block diagram of the design

1.4 GSM: (Global System for Mobile Communications)

The Global System for Mobile Communications (GSM) is a digital standard wireless technology GSM is the most widely used wireless technology in the world with one billion customers globally, which represents 72% of all wireless customers. GSM has a high presence among users (almost

everybody has a mobile) raising the probability of the remote controlled HAS to be accessible, furthermore by programming the GSM modem using AT/AT+ commands it provides another security layer (modem will respond only to specific mobiles) and certain robustness. At this backup level, the interaction with the user is very simple; the bilateral communication is reduced to the minimum, only representing emergency processes. Eventually, the remote-controlled HAS will send alerts to the user´s mobile informing about unusual state changes in the sensors within the building, afterwards user is able to activate/deactivate some automated devices required to solve the issue either by dials or messaging or, in the usual case, using a web interface, in any case the user will have always two possible accesses in case that one fails. Normally the probability of accessing the GSM network will be higher than accessing the Internet. [14].

1.5 Mobile station:

The Mobile Station represents the only part that the user will probably ever see of the whole system. It is the phone that is carried by the subscriber and used for making and receiving calls. All Mobile Stations are logically divided into two units: ME (Mobile Equipment) and SIM card, Mobile Equipment holds all the radio parts and is also capable of handling the functions required to access the network through the radio interface. This is what the user recognizes as" the phone". The SIM, Subscriber Identity Module, is a small circuit printed on a card which fits into the ME. The SIM provides the ME with subscriber information and thus allows the user to make chargeable calls. [14]

1.5.1 Output Power

GSM mobile stations are separated into classes according to their Maximum output power. The following tables shows the power classes of the mobile station according to global two GSM systems GSM900 (used in Jordan) and GSM 1800 (used in other countries):

Table.1
Output power of the two GSM systems. [15]

Power classes	GSM 900	GSM 1800
Class1	1 Watt	1 Watt
Class2	8 Watt	0.25 Watt
Class3	5 Watt	4 Watt
Class4	2 Watt	2 Watt
Class5	0.8 Watt	0.8 Watt

A GSM handheld MS may be of GSM 900 classes 4 and 5 and GSM 1800 and held MSs can be both class 1 and class 2. Both GSM 900 and GSM 1800 Mobile stations must be capable of reducing transmitter output power when instructed by the network to do so. [15]

1.5.2 Frequency bands:

For the GSM Mobile Stations, three frequency bands are defined:· Standard GSM Band: 890-915 MHz Uplink and 935-960 MHz downlink · Extended GSM Band: 880-915 MHz Uplink and 925-960 MHz downlink · GSM 1800 Band: 1710-1785 MHz Uplink and 1805-1880 MHz downlink The Mobile Station may be capable of supporting one or more of these bands. However, a procedure to select GSM 1800 operation must be provided internally in the MS if it is capable of handling both. Simultaneous use of GSM 1800 modes is not supported. [16]

1.5.3 Subscriber Identity Module – SIM:

A SIM card, also known as a subscriber identity module, is a subscriber identity module application on a smartcard that stores data for GSM/CDMA Cellular telephone subscribers. Such data includes user identity, network authorization data, personal security keys, contact lists and stored text messages. Security features include Authentication and encryption to protect data and prevent eavesdropping. The smartcard with Subscriber identity module application is generally known as **SIMCARD.** But, In reality, the SIM is effectively a mass-market smartcard. [17]

In order for the ME to operate in a GSM network for services other than Emergency services, a valid SIM-card with a valid IMSI stored on it must be present. With the insertion of the SIM card the ME will become a fully Functional Mobile Station. Certain subscriber parameters together with personal data used by the subscriber, e.g. frequently called numbers will be

stored on the SIM. Since only the SIM is required to personalize a phone it is therefore possible to rent a phone and personalize its operation with the insertion of the SIM card. This way all calls will be diverted to the new location of the SIM card wherever it is in the GSM network. [17]

1.6 RF 434 MHz transmission:

This radio frequency (RF) transmission system employs Amplitude Shift Keying (ASK) with transmitter/receiver (Tx/Rx) pair operating at 434 MHz The transmitter module takes serial input and transmits these signals through RF. The transmitted signals are received by the receiver module placed away from the source of transmission. The system allows one way communication between two nodes, namely, transmission and reception. The RF module has been used in conjunction with a set of four channel encoder/decoder ICs. Here HT12E & HT12D have been used as encoder and decoder respectively. The encoder receives data and addresses from the microcontroller, encodes them into proper frame format and sends them in series to RF transmitter. These signals are serially transferred through RF to the reception point (daughter boards). The decoder is used after the RF receiver to decode the serial format and retrieve the original signals. These outputs will be used for activating the control relays which switch on or off the end devices. [18].

1.7 Thesis outline.

1- To design and build a suitable hardware circuit in an effort to start or stop the end equipment which will receive all necessary commands and execute them.
2- To write suitable software that implements the control.
3- To get feedback from the end equipment that confirms its operational state.
4- To measure the time taken from issuing the start action control message to the time lapsed to get a completion of action message.

Chapter Two
Hardware

2.1 Introduction

The hardware part is the main part of this thesis; it is designed, built and tested to remotely control electrical equipment by sending SMSs using GSM mobile network when the mobile station is away from the end equipment (from any place in the world) or by using Bluetooth commands when the mobile is near to the equipment, then the design will inform the sender about the status of the end equipment by sending a feedback message to his mobile using GSM network, The hardware part consists of the following electronic boards:

2.2 The main board

It is the main part of the hardware system, since it receives all necessary messages from GSM modem or Bluetooth receiving device and executes the software to activate the necessary output action, and then to transmit the status of the end equipment back to the sender as SMS, the block diagram of the board is shown in figure.2,there are eight integrated circuits connected to each other in a way that we can process the received SMSs from GSM module or from Bluetooth, the main component here is the micro controller **PIC16F877**to which the software program has been downloaded to receive ,process and output the required action to the end equipment, the micro controller is connected to the GSM module through RS232 serial interface and with the Bluetooth handset through DTMF(dual tone modulation frequency), the communication between the control board and the daughter boards which activate the end equipment is established by RF (radio frequency) technology, all components of the main control board are listed and explained as follow:

1- GSM module
2- Serial interface RS232.
3- Voltage regulator.
4- RF encoder HT12E.
5- RF decoder HT12D.
6- PIC 16F877A.
7- DTMF (Dual Tone Multi Frequency).
8- Level shifter (MAX232).
9- RF 434 MHz transmitter.
10-RF 434 MHz receiver.
11-LEDs (Light Emitter Diodes)

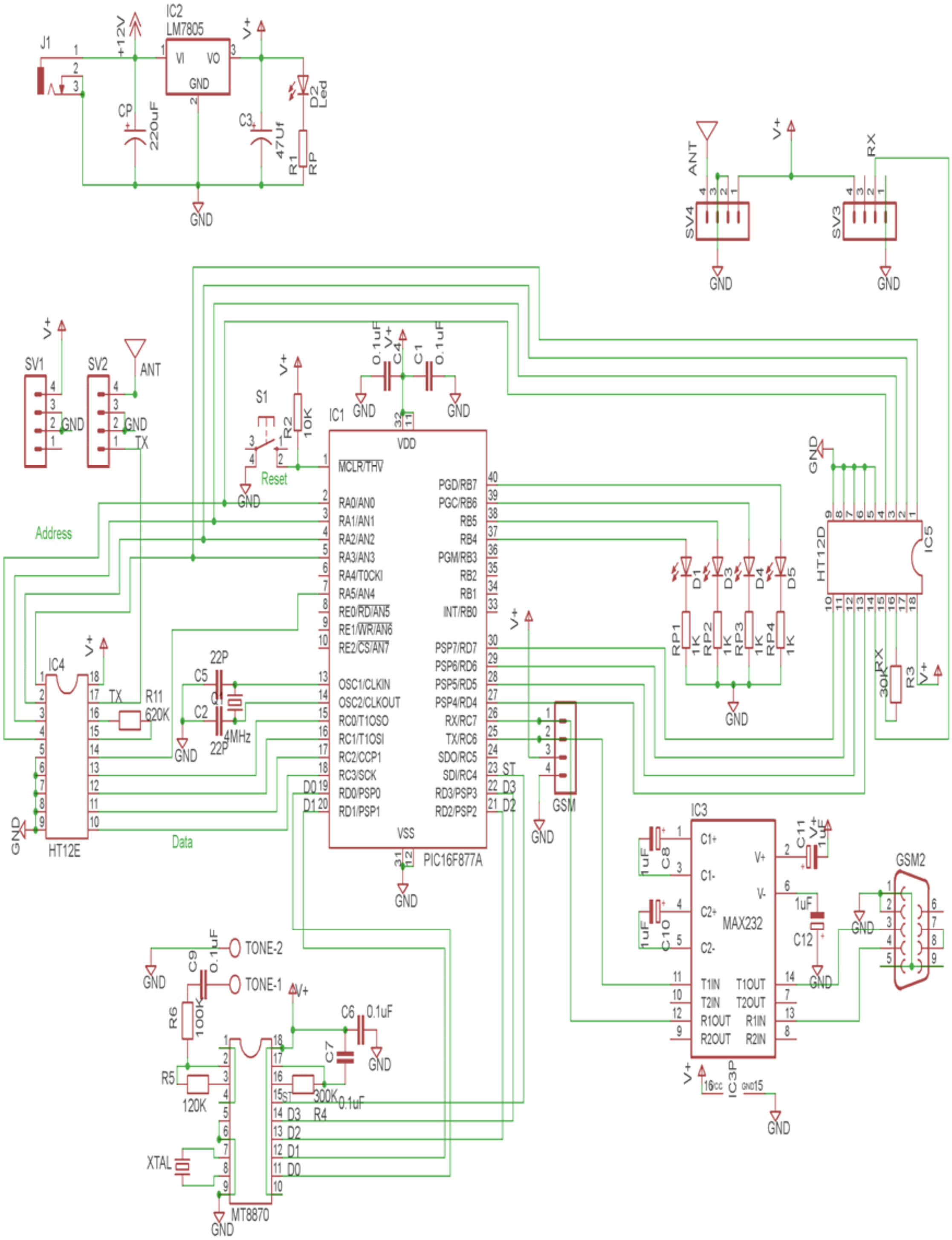


Fig. (2)
Main control board

2.2.1 GSM Module:

Global system for communication module, is a small module in which the SIM card is inserted for activating the wireless link with the existing cellular system for receiving SMSs, this module is located on the GSM modem Which is separately located from the main board but connected to it by RS232 interface as shown in the figure.2 by 9-pin port, pins number 3 and 4 are used to transmit and receive commands from and to the GSM module, of course all massages received from remotely located user are transferred to the PIC (16F877A) in the main board for processing and executing the necessary output action. The modem part provides with minimal component's list all functionality necessary for voice and data transmission over GSM and GPRS network. The modem is divided in an area surrounded by traces on which metal box must be soldered. This area encloses the RF High power components, the remaining passive components of the transceiver, the base band processor, memory, crystals and power management unit. The modem is designed as a dual-band transceiver, i.e. GSM850 / PCS1900 or EGSM900 / DCS1800.TM1 is a small, readymade light weight and low power consumption module ,it is separately located from the main board and connected to it through interface R232, this module enables digital communications services on GSM/GPRS networks for machine to machine, user to user or user to machine wireless applications, it is a readymade device and separately located from the main board, its connected to the main board through RS232 interface which is shown in figure.2, These GSM/GPRS data modules are developed in compliance with internal and normative certification requirements.[19]

2.2.2 GSM Modem:

The modem part provides with minimal component's list all functionality necessary for voice and data transmission over GSM and GPRS network.
The modem is located separately from the main control board, itis a readymade device and connected to the boardby RS232 interface as shown by 9-pin port in the main control board and it is supplied by 5 VDC separately, it is divided in an area surrounded by traces on which metal box must be soldered. This area encloses the RF High power components, the remaining passive components of the transceiver, the baseband processor, memory, crystals and power management unit. The modem is designed as a dual-band transceiver, i.e. GSM850 /PCS1900 or EGSM900 / DCS1800. [19]

2.2.3 GSM module power supply

TM1 Data Module can be supplied by an external power supplier connected with the mother board of the GSM modem. The typical voltage of the module is 3.8 VDC and supplied from the mother board of the GSM modem.[19]

Table.2
GSM power supply

Description	Min	Type	Max
Supply voltage	3.5	3.8	4.2

The VBAT voltage is connected with the power management part of the baseband chipset on the modem board that supplies all components of the data module and derives all needed voltage levels to supply the different circuit parts; the power amplifier is supplied directly by VBAT (Voltage BATarry).[19]

2.2.4 Serial Interfaces:

TM1 Data Module offers to the user the possibility to use a serial port, which is shown in FIG.2 as 9-pin port with numbers from 1 to 9, here pin numbers: 3 and 4 are used for transmit and receive data with the GSM module using ITU V.24 protocol Default baud rate is 115.2 Kbps; data rate maximum is 920 Kbps. Main features of ASC serial port are reported in the following:

1- Complete 9-pin serial port;
2- Mux protocol (GSM 27.010);
3- Power saving available;
4- Interface (present on the mother board) is fully RS232 9-pin compliant;
5- HW flow control supported;
6- Used for AT commands interface.

The available signals for ASC serial port are:

1- Data Carrier Detect (DCD);
2- Data Terminal Ready (DTR);
3- Clear to Send (CTS);
4- Request to Send (RTS);
5- RX Data (RXD);
6- TX Data (TXD);
7- Ring Indicator (RI);
8- Data Set Ready (DSR).

The design of the data module is carried out to use the data module as a DCE, while the application will be a DTE. Hence with the signal RXD the data module will receive the data sent by the DTE, while with TXD the data module will transmit the data to the DTE. [20]

In table.4 below the pins of the board-to-board connector of the serial ports are described:

Table.3
Serial Interface Pins [20]

Name	PIN#	I/O	I/O type	Description
DSR	23	O	Generic digital signal	Data Set Ready
RI	24	O	Generic digital signal	Ring Indicator
DCD	25	O	Generic digital signal	Data carrier ready
DTR	26	I	Generic digital signal	Data Terminal Ready
CTS	27	I	Generic digital signal	RTS (DCE)
RTS	28	O	Generic digital signal	CTS (DCE)
RXD	29	I	Generic digital signal	RX (DCE)
TXD	30	O	Generic digital signal	TX (DCE)

2.2.5 RS232:

The RS-232 interface is the Electronic Industries Association (EIA) standard for the interchange of serial binary data between two devices, it is used here for communication between the GSM modem and the main control board; the standard allows as many as 20 signals to be defined, but gives complete freedom to the user. Three wires are sufficient: send data, receive data, and signal ground. The remaining lines can be hardwired on or off permanently. The signal transmission is bipolar, requiring two voltages, from 5 to 25 volts, of opposite polarity.

The baud rate at which the word sent is device-dependent. The baud rate is usually 150 times an integer power of 2, ranging from 0 to 7 (150, 300, 600, and 19,200). Below 150 baud, many system-unique rates are used. The modem signals are not needed when a computer terminal is connected directly to a computer; Figure2 illustrates the pin numbering of RS232 interface used in the communication between the main control card and GSM module. [21].

2.2.6 Advantages of serial communication:

Serial communication has some advantages over the parallel communication. One of the advantages is transmission distance, serial link can

send data to a remote device more far then parallel link. Also the cable connection of serial link is simpler then parallel link and uses less number of wires. [21]

2.2.7 Communication methods of serial transmission:

There are two methods for serial communication, Synchronous & Asynchronous.in this design the Asynchronous method is used.

2.2.7.1 Synchronous serial communication:

In Synchronous serial communication the receiver must know when to “read” the next bit coming from the sender, this can be achieved by sharing a clock between sender and receiver.

In most forms of serial Synchronous communication, if there is no data available at a given time to transmit, a fill character will be sent instead so that data is always being transmitted. Synchronous communication is usually more efficient because only data bits are transmitted between sender and receiver, however it will be more costly because extra wiring and control circuits are required to share a clock signal between the sender and receiver.[22]

2.2.7.2 Asynchronous serial communication:

Asynchronous transmission allows data to be transmitted without the sender having to send a clock signal to the receiver. Instead, special bits will be added to each word in order to synchronize the sending and receiving of the data.When a word is given to the UART for Asynchronous transmissions, a bit called the "Start Bit" is added to the beginning of each word that is to be transmitted. The Start Bit is used to alert the receiver that a word of data is about to be sent, and to force the clock in the receiver into synchronization with the clock in the transmitter. [22]

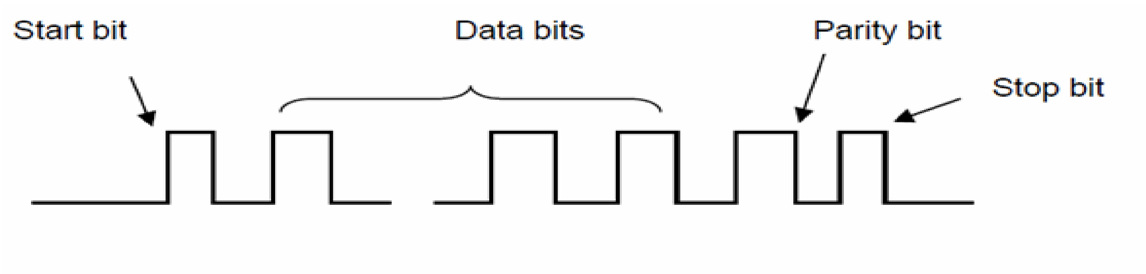


Fig (3)
Example of serial data transmission

2.2.8 Voltage regulator

The LM341 and LM78MXX series of three-terminal positive voltage regulators employ built-in current limiting, thermal shutdown, and safe-operating area protection which make them virtually immune to damage from output overloads.

With adequate heat sinking, they can deliver in excess of 0.5A output current. Typical applications would include local (on-card) regulators which can eliminate the noise and degraded performance associated with single-point regulation. This integrated circuit "voltage regulator" is shown in figure.2 as IC2 (LM7805) and separately in figure.5, this device has three terminals with numbers: 1, 2 and 3, terminal#1 receives the main input voltage (12VDC), and the output terminal#2 outputs 5 VDC with sign "V+" and distribute this voltage values to all integrated circuits of the main control board and the terminal#3 goes to ground.

This kind of regulators has the following characteristics:

1- Output current in excess of 0.5A
2- No external components
3- Internal thermal overload protection
4- Internal short circuit current-limiting
5- Output transistor safe-area compensation
6- Available in TO-220, TO-39, and TO-252 D-PAK Packages
7- Output voltages of 5V, 12V, and 15V

For detailed information, the datasheet of this device is included in appendix II.

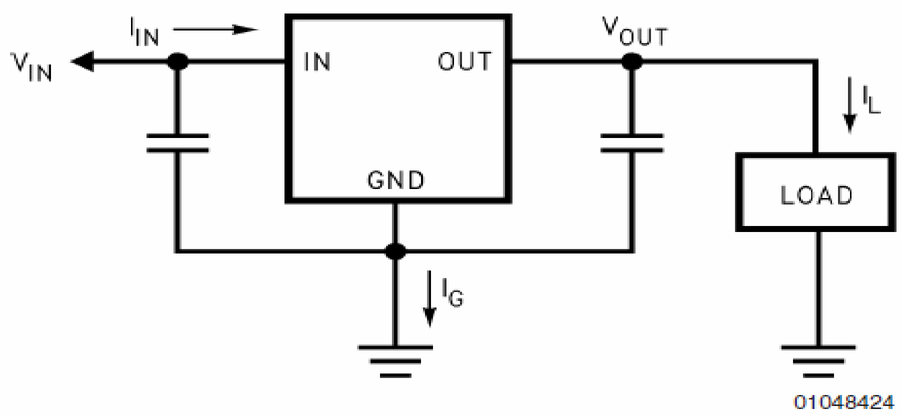
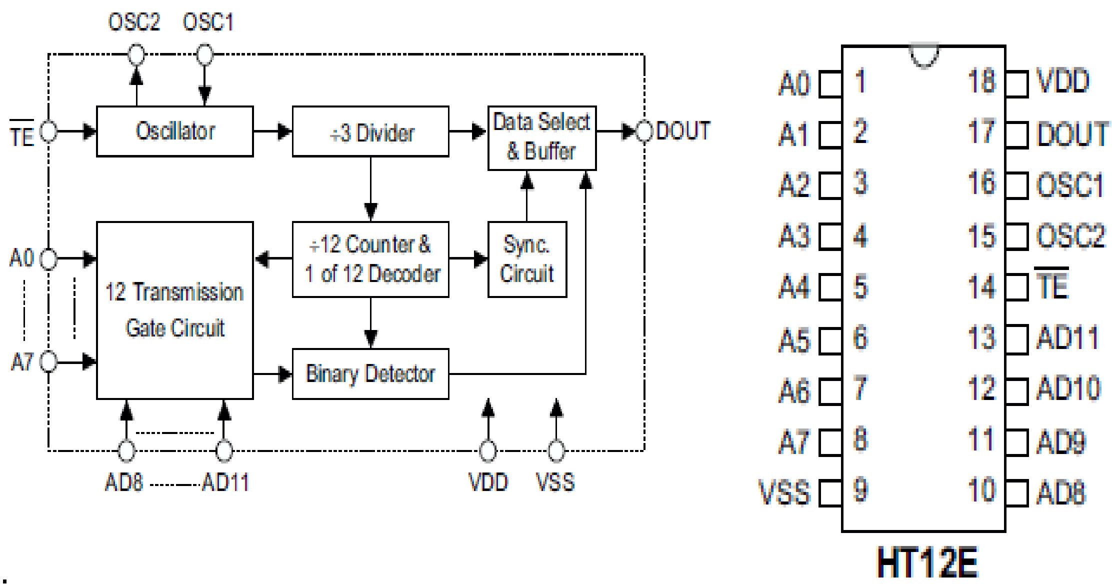


Fig. (4)
Voltage regulator

2.2.9 Encoder HT12E:

The 212 series encoders are a series of CMOS LSIs for remote control system applications. They are capable of encoding information which consists of N address bits and 12_N data bits. Each address/data input can be set to one of the two logic states. The programmed addresses/ data are transmitted together with the header bits via an RF or an infrared transmission medium upon receipt of a trigger signal. The capability to select a TE (transmit enable) trigger on the HT12E or a DATA trigger on the HT12A further enhances the application flexibility of the 212 series of encoders. The HT12A additionally provides a 38 kHz carrier for infrared systems. Its datasheet is included in Appendix III.

The encoder is shown in figure.6,it has 18 pins, the pins from 5 to 9 are grounded, the pins from 10 to 13 are used for data from the microcontroller (PIC16F877A), The pins from 1 to 3 are used for receiving address of the required daughter board from the microcontroller (PIC16F877A), the pin 18 is for voltage supply with sign(V+) and the pin 16 is used for transmitting the data which contains the address and the command to the required daughter board via RF antenna, so the encoder receives the data and address from the microcontroller then encodes this information (address and data) and transmits it via RF transmitter to the require daughter board.



.

Fig. (5)
HT12E encoder.

2.2.10 Decoder HT12D:

The HT12D decoder is used in the main control board and shown in figure.2 IC5 (HT12D), it is used to receive data from the RF transceiver from the daughter boards at pin 14, this data represents the status of the end equipment, after decoding it sends it to the microcontroller PIC16F877 through pins: 10-13, the unit is supplied by 5 VDC through pin 18. For detailed information, the datasheet of this device is included in Appendix V.

2.2.11 PIC (16F877AP Microcontroller)

The primary role of the Microchip PIC and other embedded microcontrollers is to provide inexpensive, programmable logic control and interfacing to external devices. This means they typically are not required to provide highly complex functions, they are well suited to monitoring a variety of inputs, including digital signals, button presses, and analog inputs, and responding to them using the preprogrammed instructions that are executed by the built-in computer processor. An embedded microcontroller can respond to this input switch a wide variety of outputs that are appropriate for different devices. These capabilities are available at a very reasonable cost without a lot of effort. All microcomputer systems, irrespective of their complexity, are based on similar building as shown in figure.7 [23]

They are consisting of the following:

1- CPU - the part that carries out all logic and arithmetic functions
2- RAM - storage for programs and/or program variables
3- ROM - read-only parts of programs
4- I/O - connection to external devices

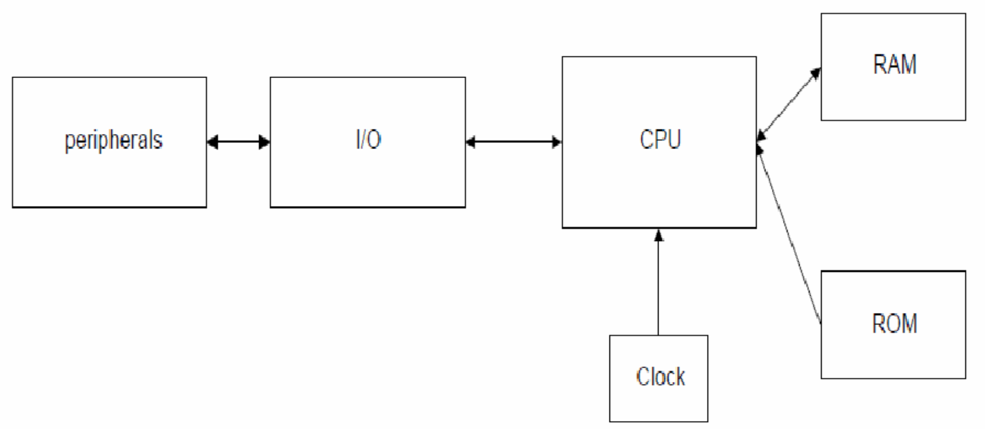


Fig. (6)
Basic building blocks of a computer

The CPU or microprocessor is the core component of any microcomputer and it requires external components such as the ROM, RAM, I/O etc. to accomplish its purpose.

The microcontroller based system requires no additional circuitry except a clock input and it can, in many cases, directly drive peripheral outputs. The difference between the microprocessor and the microcontroller arises because of their different end-usage.

It is consisting of the following units:

1- CPU: Central Processing Unit.
2- RAM &ROM.
3- Analog I/P.
4- Digital I/O.
5- Clock Device
6- Processor reset.
7- Interrupt Capability.
8- Serial I/O.
9- Instruction Cycles sequencer (PC: Program Counter).
10- Instruction Set Register (Inst.Set).
11. Variable Ram.

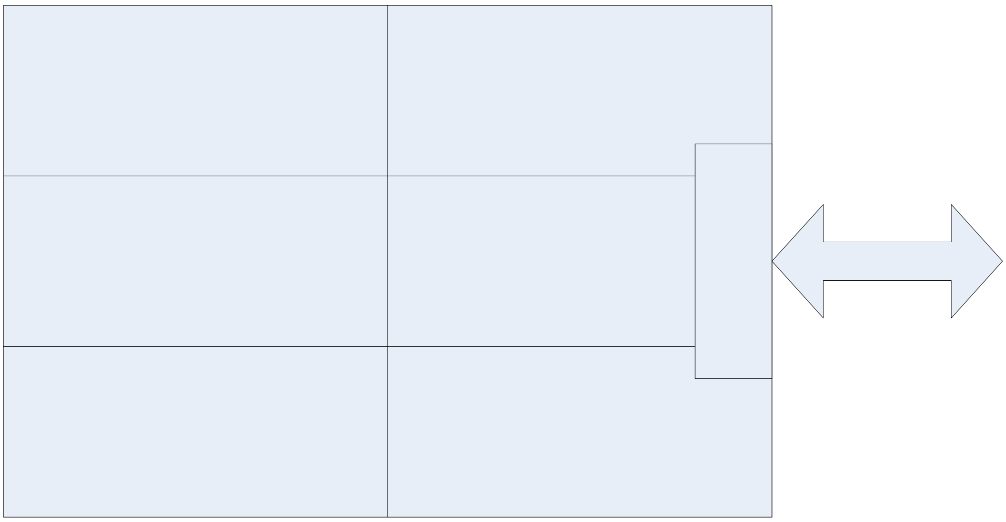


Fig. (7)
(PIC16F77A) Block Diagram

2.2.11.1 Architectures of CPU

There are two structures in this architecture

A-CISC (Complex Instruction Set computer)

1- It has a large number of Instructions, like Motorola processors. Accessing data direct through index registers, without using accumulator
2- Faster than RISC but have more instruction.

B- RISC(Reduced Instruction set computer)

1- It has a minimum number of Instructions.
2- Accessing data through accumulator register.

2.2.11.2 Memory layout

The PIC16F877 has 8K x 14-bit words of Flash program memory, 368 bytes of data RAM, 256 bytes of data EEPROM and an 8-level x 13 bit wide hardware stack as shown in Figure.10.

The Program Counter (PC) is 13 bits wide, thus making it possible to access all 8K of addresses; the low byte is the PCL (Program Counter Low byte) register which is a readable and writable register. The high byte of the PC (PC<12:8>) is not directly readable or writable and comes from the PCLATH (Program Counter LATch High) register. The PCLATH register is a holding register for the PC<12:8>. The contents of the PCLATH are transferred to the upper byte of the program counter when the PC is loaded with a new value. Although the PC is capable of addressing the entire program memory space, conceptually the program memory is represented by four banks of 2K x14-bit words. Banking is necessary since there are only 11 bits for the address in the instruction word for a call or go to. The other two bits are obtained from the top two bits of PCLATH (i.e.PCLATH<4:3>). This means that the user must set those extra bits in PCLATH before branching out of the 2K bank that contains the current instruction. Within the program memory space, the reset vector (location to go to on reset) is at 0000hand the interrupt vector (location to go to on interrupt) is at 0004h (h-hexadecimal).The data memory space effectively has 9 bit addresses, and is also banked. There are 4 banks; each bank holds 128 bytes of addressable memory. The banked arrangement is necessary because there are only 7 bits are available in the instruction word for the addressing of a register, which gives only 128 addresses. The selection of the banks is determined by control bits RP1, RP0 (Register-Pair higher Bank- Register Pair Lower Bank Bits) in the STATUS register (STATUS<6:5>). Together the RP1, RP0 and the specified 7 bits effectively form a 9 bit address. The first 32 locations of Banks 1 and 2, and the first 16 locations of Banks 2 and 3 are reserved for the mapping of the Special Function Registers (SFR's). SFRs (e.g. PC, STATUS) are used to control the operation of the microcontroller as well as peripherals

such as the I/O ports. The SFRs are mapped into the data memory space to facilitate addressing, the 368 bytes of static RAM which are used as general purpose registers (GPR), are arranged in the data memory space so that each is accessed by a unique address, with the exception of the last 16 bytes of each bank, which are shared. Each mapped SFR and GPR is 8-bits wide, the entire data memory can be accessed either directly using the absolute address of each register file, or indirectly through the Indirect File (INDF) register and the File Select Register (FSR). The INDF register is not a physical register. [23]

2.2.11.3 Memory Types

There are three types in PIC MCU:

1. Random Access Memory (RAM).
2. Electrical Erasable Programmable ROM (EEPROM).
3. Flash: You can’t write and erase on specific location, it erase All and write all.

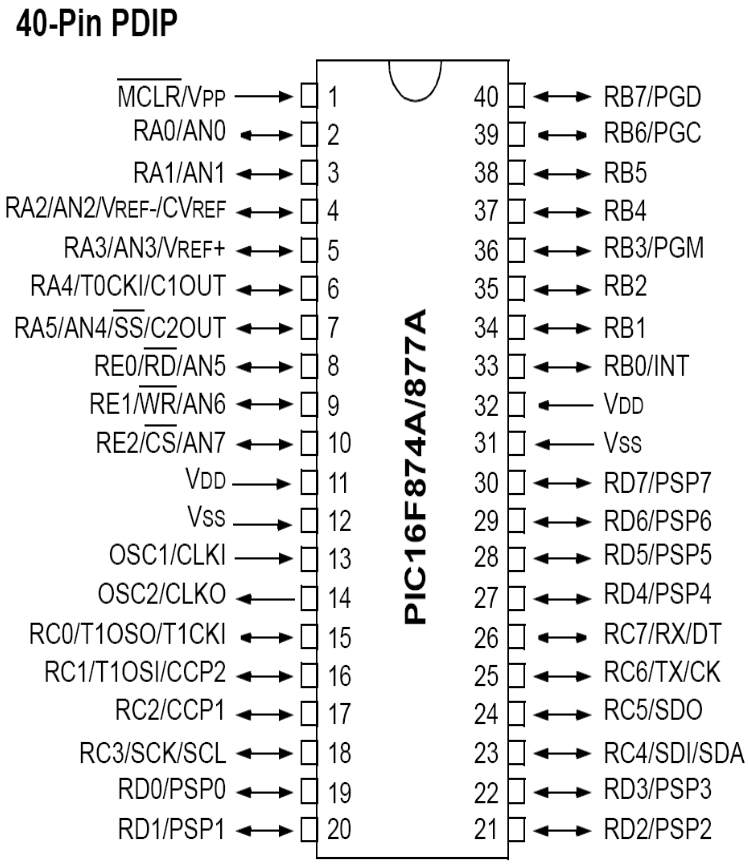
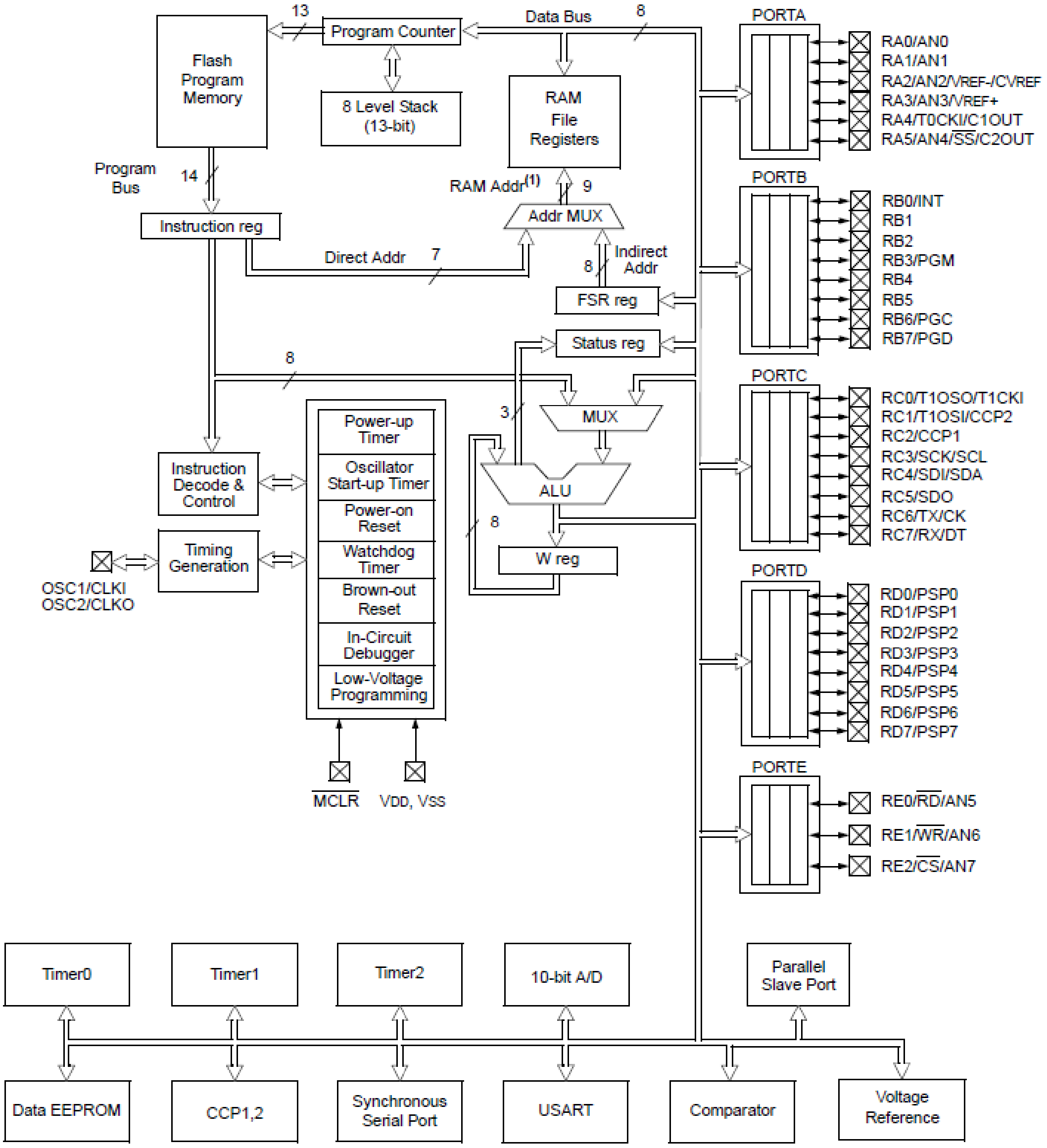


Fig. (8)
Integrated circuit of PIC16F877A



Device	Program Flash	Data Memory	Data EEPROM
PIC16F874A	4K words	192 Bytes	128 Bytes
PIC16F877A	8K words	368 Bytes	256 Bytes

Note 1: Higher order bits are from the Status register.

Fig. (9)
PIC16F877A. [23]

2.2.12 DTMF (Dual Tone Multi Frequency):-

The MT8870D/MT8870D-1 monolithic DTMF receivershown in figure.2 (IC6 MT8870) offers small size, low power consumption and high performance. It is used to receive the tone frequency of the pressed key from the phone received by Bluetooth headset connected to the main board

Duel Tone Multi Frequency (DTMF) IC is used to identify which key is pressed in the mobile keypad. Mobile keypad is used as password entry device. Pressing any key generate unique tone which consists of two different frequencies one each of higher and lower frequency range. The resultant tone is convolution of two frequencies.The frequencies and their corresponding digits are shown in Fig 2.1.

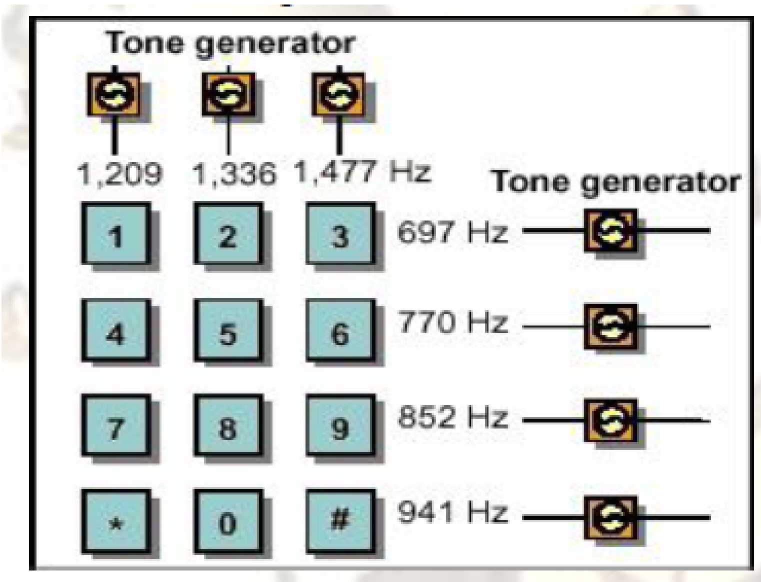


Fig. (10)
Phone keypad for DTMF tone generation

Each of these tones is composed of two pure sine waves of the low and high frequencies superimposed on each other. These two frequencies explicitly represent one of the digits on the telephone keypad. Thus generated signal can be expressed mathematically as follows: [24]

$f(t) = AH \sin(2\pi fH\, t) + AL \sin(2\pi fL\, t)$ (1)

Where AH, AL are the amplitudes and fH, fL are the frequencies of high and low frequency range. Properties of DTMF tone frequencies are: [22]

1- No frequency is an integer multiple of another

2- the difference between any two frequencies does not equal any of the frequencies
3- the sum of any two frequencies does not equal any of the frequencies

The DTMF receiver consists of 18 pins, pin 18 is used for power supply (5VDC) it is shown as "V+",pins:((3,4,16 and 17) are used for receiving the frequencies of the pressed key through Bluetooth headset, after decoding the received frequencies, the receiver (DTMF) transmits four bits through pins from 11 to 14 to the PIC16F877, as shown in figure.11.

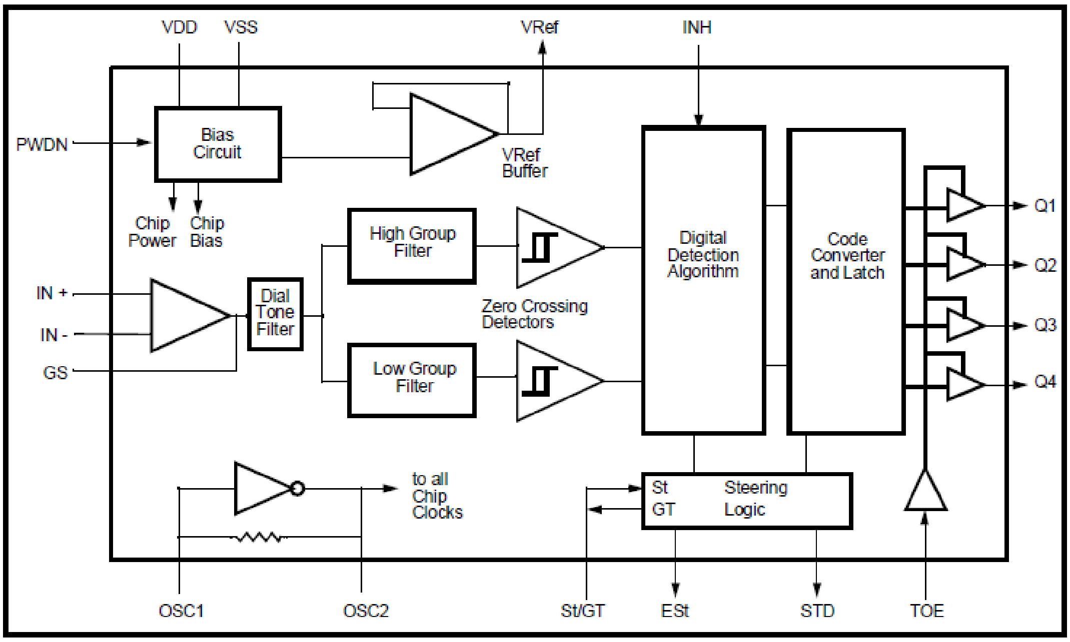


Fig. (11)
DTMF block diagram

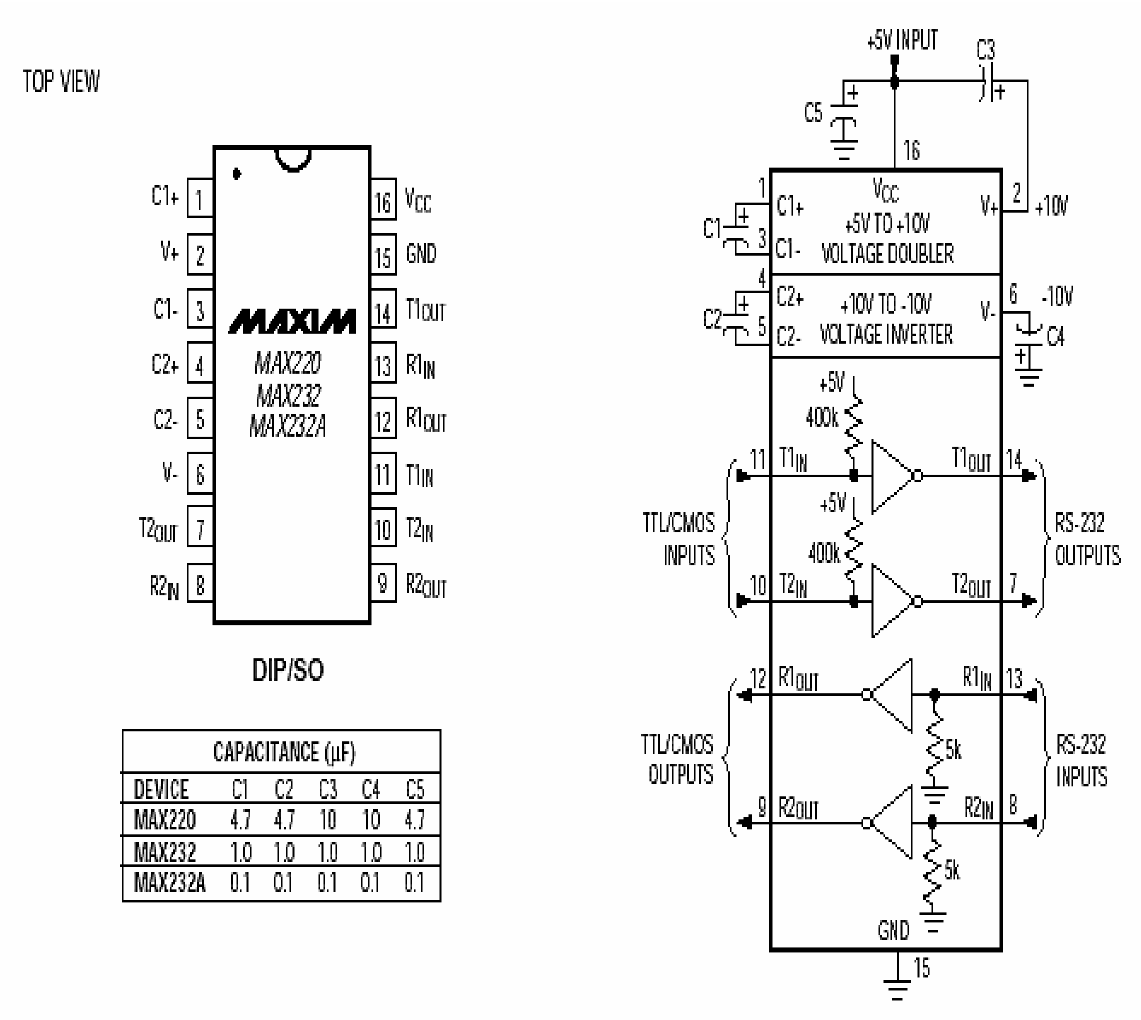
The output four bit code of the DTMF receiver is received by The PIC16F877 at pins 19,20,21,22 then, itis processed and activates the necessary output action to the required daughter boardfor the required equipment.Data sheet of this device is attached in appendix V.

2.2.13 MAX232 (level shifter):

The integrated circuit MAX232 is shown in figure.2 IC3, it is one of the most used level shifters for the (RS232-) serial port of PCs (EL3-07301). Often only the TTL-voltage-levels are available, but for the communication with RS232 standard one needs voltages of +12 V and -12 V. A separate supply voltage would be a high amount. The MAX232 needs only one supply voltage of 5V.It generates itself the levels of +10 V and -10V. The needed

external elements are only 4 capacitors with nearly 1µF.The MAX232 is connected to RS232 port by pins 3 and 4,it receives data from RS232 at pin4 of 12vdc and converts it to 5 VDC, then it transmits it to the microcontroller (PIC16F877) at pin 12,It receives from the microcontroller at pin 11 data of level 5VDC, then it converts it to level 12VDC and transmits it at pin 14 to RS232 port. The integrated circuit MAX232 is supplied by 5 VDC at pin 2,MAX232 is a dual driver/receiver that includes a capacitive voltage generator to supply TIA/EIA-232-F voltage levels from a single 5-V supply. Each receiver converts TIA/EIA-232-F inputs to 5-V TTL/CMOS levels. These receivers have a typical threshold of 1.3 V, a typical hysterics of 0.5 V, and can accept ±30-V inputs. Each driver converts TTL/CMOS input levels into TIA/EIA-232-F levels. The driver, receiver, and voltage-generator functions are available as cells in the Texas Instruments LinASIClibrary. The MAX232 has two integrated DC-DC-converters, one for the doubling of the voltage (+10V) and one as voltage inverter (-10V). The MAX232 has two shifters for TTL to RS232 and two for RS232 to TTL. For detailed technical information

Its Datasheet is included in Appendix VI.



CAPACITANCE (µF)					
DEVICE	C1	C2	C3	C4	C5
MAX220	4.7	4.7	10	10	4.7
MAX232	1.0	1.0	1.0	1.0	1.0
MAX232A	0.1	0.1	0.1	0.1	0.1

Fig. (12)
Integrated circuit of MAX232

2.2.14 RF434Mhz transmitter:

This unit is made up of the TWS-433 MHZ transmitter. The RF transmitter a readymade device and is not shown in figure.2, its socket is shown and operates at 434 MHz and has an output that is up to 8 mW using amplitude modulation (AM) technique and operates between 5 V - 12 V DC. it is used in the main control board to transmit signals to daughter boards through HT12E encoder to pass it to Antenna which sends it to required daughter board, which according to their addresses respond to these commands, and activate the necessary circuit (end equipment, like motor, lamp or pump). [25]

2.2.15 RF434Mhz receiver:

It is used in the main board to receive RF434mhz signals from daughter boards and pass them to decoder HT12D then to PIC16F877A.

2.2.16 LEDs (Light Emitter Diodes):

These LEDs are used to indicate the following actions:

1- The first LED is on when the commands are being received from Bluetooth and it is off when the commands received from GSM module it is connected to port RB4 of the PIC26F877A
2- The second LED is switched on when the command is transmitted to switch light on and switches off when light is switched off. It is connected to the port RB5 of the PIC16F877A
3- The third LED is switched on when the command is transmitted to start the door motor and switches off when motor is stopped. It is connected to the port RB6 of the PIC16F877A
4- The fourth LED is switched on when the command is transmitted to start motor3 (pump) and switches off when motor is stopped. It is connected to the port RB7 of the PIC16F877A.

2.3 Daughter board:

There are three daughter boards used in this design, each of them is located at distance away from the main board about 20 to 150 meters (RF434mhz range), the RF transceiver receives the data from the main board and passes it to the decoder (HT12D), the decoder compares the address with its own address set by dip switches on the daughter board, then if this matches the data will be passed to the microcontroller(PIC16F84) for further processing, after that it compares the address with its local address configured by dip switches, if the addresses don't match it ignores the data which means that the data is not assigned to it, as explained previously, the communication between the daughter boards and control board is established using RF technology.

The daughter board is shown in figure.14 and consists of the following components:

1- Voltage regulator.
2- RF transmitter.
3- RF receiver.
4- Decoder HT12D.
5- Encoder HT12E.
6- PIC16F84.
7- Power relay.

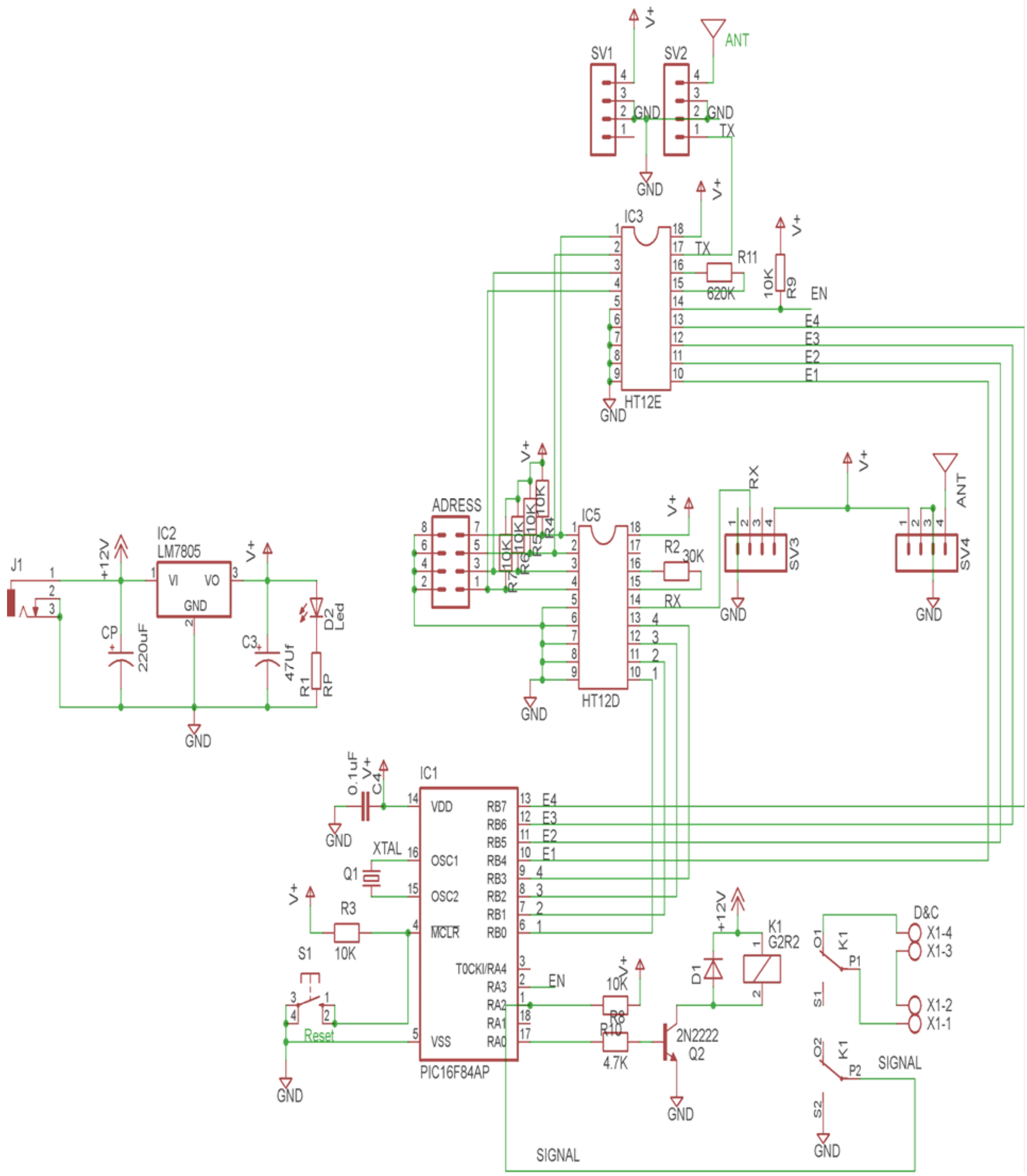


Fig. (13)
Daughter board

Table.4
Daughter board physical addresses

Daughter board name	Daughter board address set locally by dip switches
1- Light board	0000
2- Door motor board	0001
3- Pump motor board	0010

In the future and for expansion purposes these daughter boards can be extended by building new boards with new addresses. Every board consists of the following components:

2.3.1 Voltage regulator:

It is the same regulator which is used in the main board; it is supplied by 12vdc and fixes the output at 5vdc which is used as power supply for all components in the circuit.

2.3.2 RF transmitter:

This is a radio frequency transmitter it is the same as one used in the main board, it is a readymade circuit and not shown in schematic diagram of the design figures, its connection socket is shown in figure.14 (SV1, SV2, SV3 and SV4), this transmitter sends feedback signal to the main board which contains the status of the equipment, the main board processes it and transmit SMS back to the sender using GSM modem.

2.3.3 RF receiver:

It is the same one used on the main control board, here it receives the signals from the main board and pass them to the decoder HT12D, after decoding, it is transmitted to the PIC16F84.

2.3.4 Decoder HT12D:

Data received by the RF receiver circuit is directly transferred to this unit,this unit is shown in figure.14 IC5 (HT12D), it receives data at pin 14 directly from the RF receiver, after decoding the data is sent to the microcontroller (PIC16F84 through pins: 10-13, this unit is supplied by 5 VDC at pin 18,The 212 decoders are a series of CMOS LSIs for remote control system applications. They are paired with Holtek_s 212 series of encoders (refer to the encoder/decoder cross reference table). For proper operation, a pair of encoder/decoder with the same number of addresses and data format should be chosen. The decoders receive serial addresses and data

from a programmed 212 series of encoders that are transmitted with their local addresses. If no error or unmatched codes are found, the input data codes are decoded and then transferred to the output pins. The VT pin also goes high to indicate a valid transmission. The 212 series of decoders are capable of decoding information that consists of N bits of address and 12_N bits of data.

Of this series, the HT12D is arranged to provide 8 address bits and 4 data bits, they compare the serial input data three times continuously.

The datasheet is included in Appendix IV.

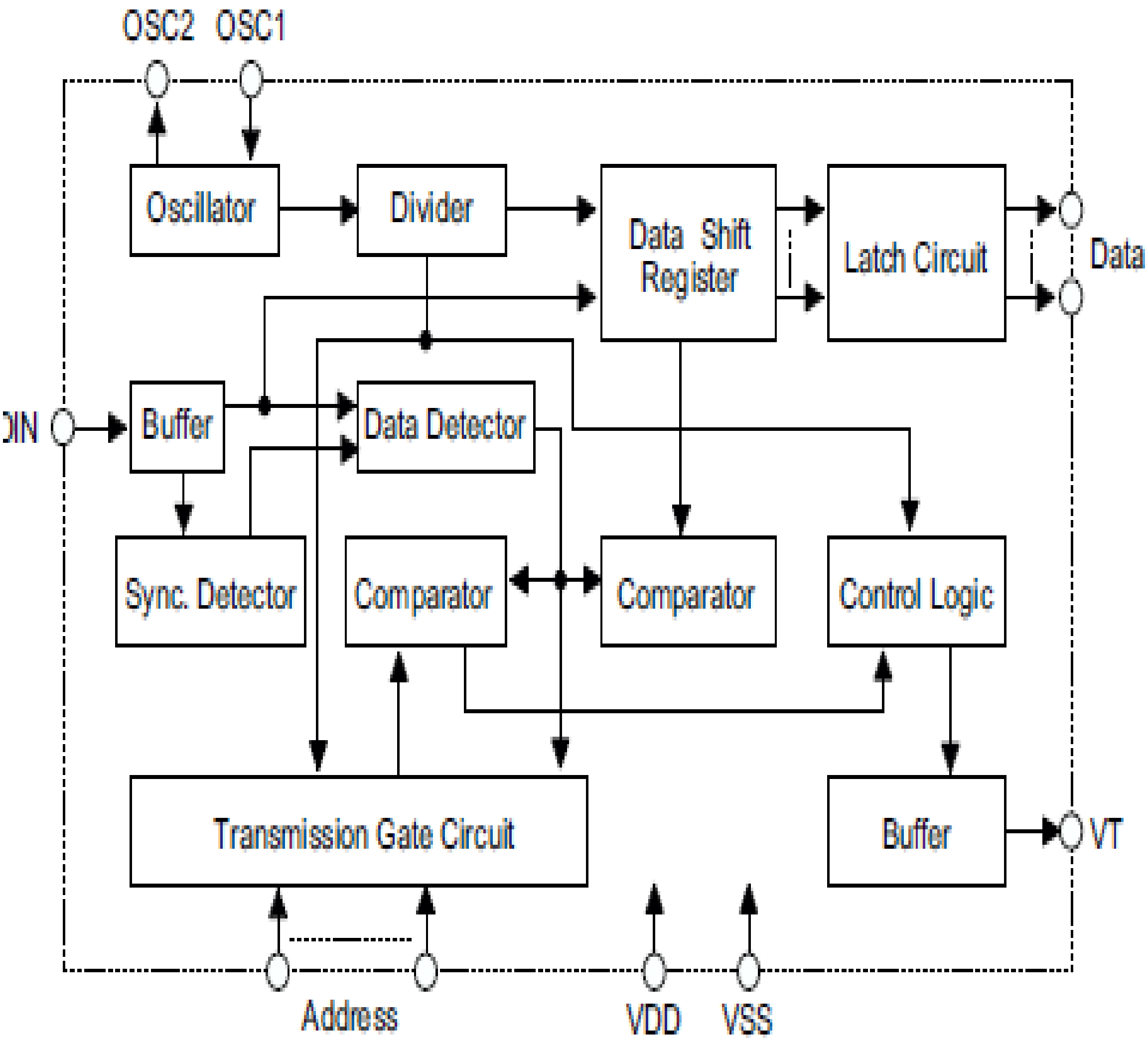


Fig. (14)
HT12D Decoder block diagram

2.3.5 Encoder HT12E:

This is an encoder, it is the same as the unit used in the main board, it is used in daughter board to send the status of the equipment back to the main board, and it is shown in figure.14 IC3 (HT12E).

2.3.6 PIC16F84A:

PIC16F84A is used in daughter board and shown in figure.14 as a main unit which receives all data from the decoder and processes it, then activates the output power relay, which in sequence passes power (220VAC) to the required motor, or to light the required lamp. The difference between **PIC16F84A** and **PIC16F877A** is that**, PIC16F84** doesn't have **UART** unit by which the PIC can connect with RS232 interface and has less digital inputs and output's channels also it doesn't have analogue input channels so it is cheaper than PIC16F877A and it is suitable to be used for daughter boards.

The PIC16F84A belongs to the mid-range family of the microcontroller devices. A block diagram of the device is shown in Figure 16.The program memory contains 1K words, which translates to 1024 instructions, since each 14-bit program memory word is the same width as each device instruction.

The data memory RAM) contains 68 bytes. Data EEPROM is 64 bytes.

There are also 13 I/O pins that are user-configured on a pin-to-pin basis.

Some pins are multiplexed with other device functions. These functions include: [26]

1- External interrupt
2- Change on PORTB interrupts
3- Timer0 clock input

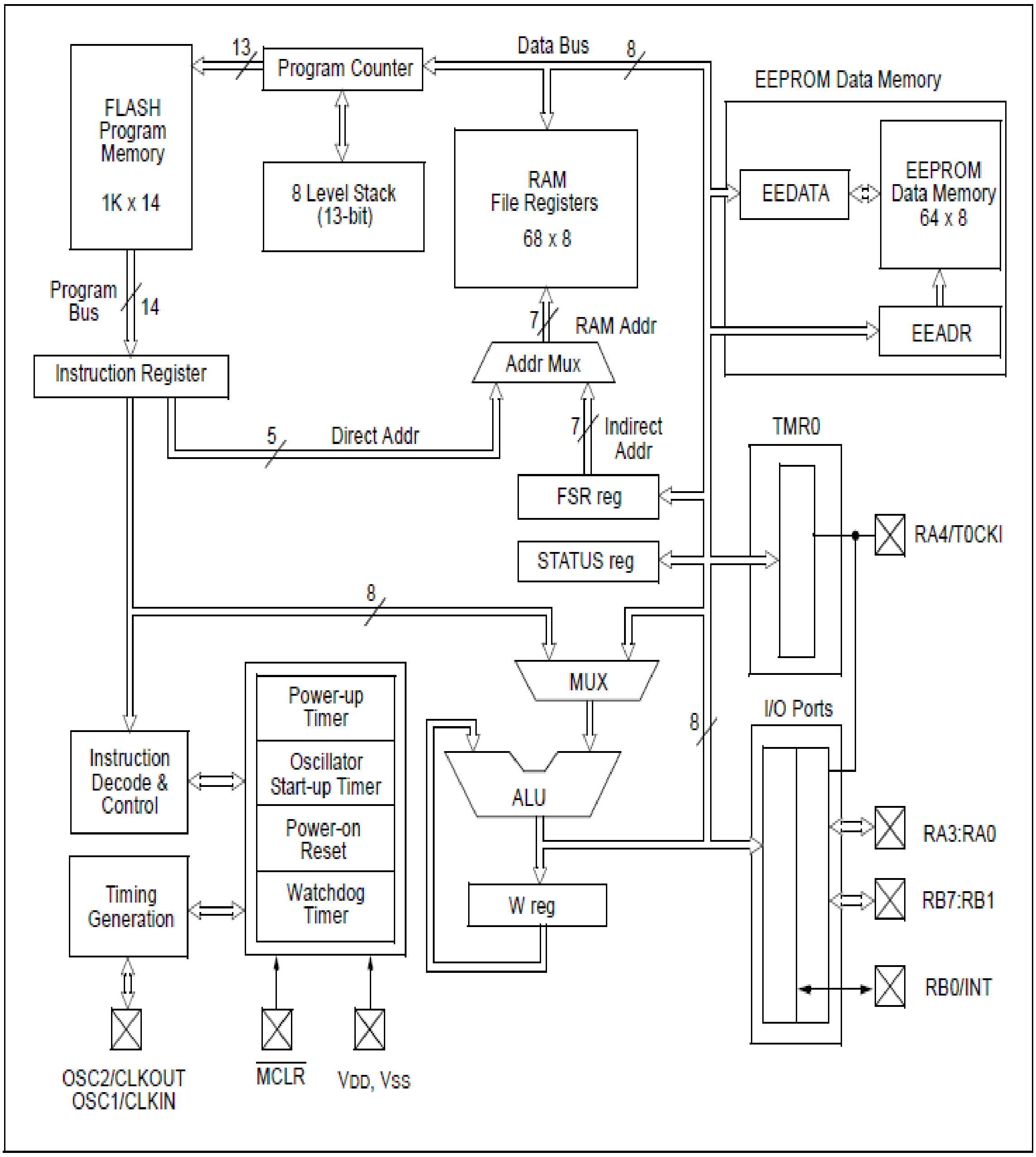


Fig. (15)

PIC16F84A block diagram [24]

2.3.7 Power Relay:

It is a power device shown in figure.14 and separately shown in figure.17, the low voltage signal applied from the PIC16F84 as output signal to the base of the npn transistor, the transistor Q2 is switched on, then a 12VDC supplies the coil of the relay K1, it energizes and closes the two contacts S1 and S2, contact S1 will pass power to the motor to start, and contact S2 will pass feedback signal to the PIC16F84 which indicates the status of the end equipment (for example motor is running).

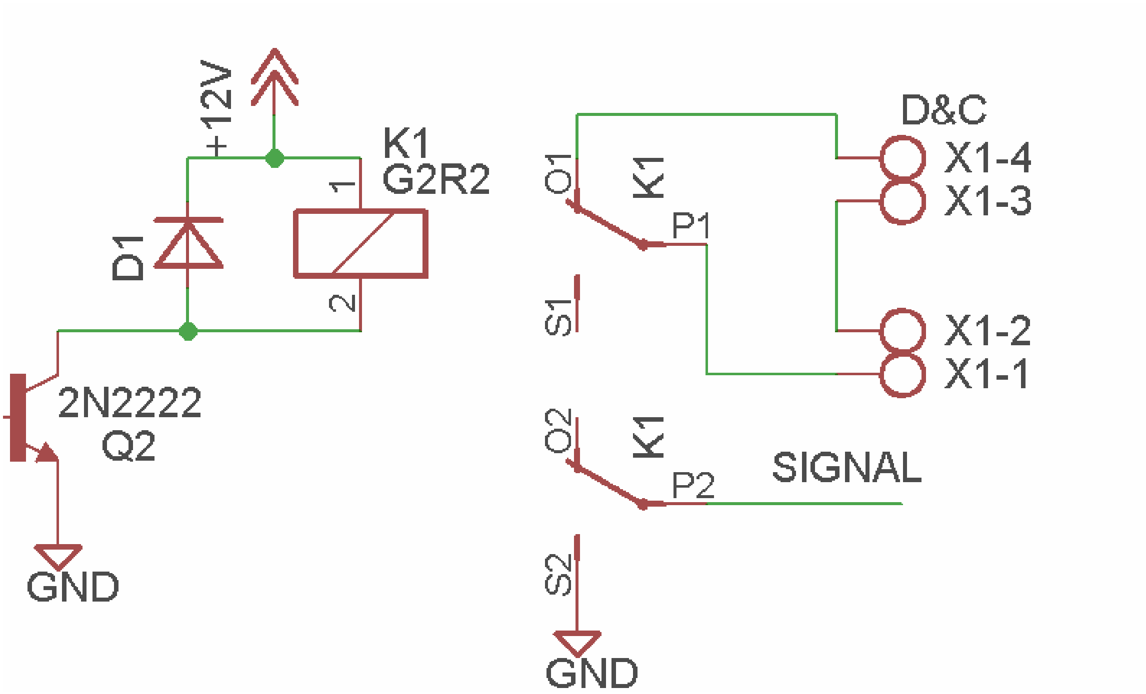


Fig. (16)
Power relay

Chapter three
Software

3.1 Introduction

A listing of software used in this prototype design is included in this document as shown in Appendix A; the software contains two parts. One is the programming of the microcontroller **PIC16F877A** in the main control board and the other is for the microcontroller **PIC16F84A** on the daughter board which is for the end equipment (motor or pump or light).As it is shown in previous chapter, the main control board is consisting of **PIC16F877A** and other necessary electronic components to execute commands received from GSM module as SMS or DTMF over Bluetooth as tones, this card cannot work without suitable software programming, so the program code was written using micro basic code editor, and after compiling it, the program was downloaded to the Microcontroller PIC16F877A. As shown in the block diagram of the main control board, the microcontroller is connected with the GSM modem using RS232 interface and with the Bluetooth handset via DTMF integrated circuit ,so the micro controller executes the program in sequence action, and every time checks the GSM modem for available received SMSs, so it takes the message and output the desired action according to received message, the software program used in this thesis is a micro basic for several micro controllers, the program text will be included in this thesis as Appendix I**.**

3.2 Micro basic overview:

Micro basic is a Windows-based Integrated Development Environment, and is much more than just Basic compiler for PIC MCUs. With microBasic, one can:

1. Create Basic source code using the built-in Code Editor
2. Compile and link the source code
3. Inspect program flow and debug executable logic with Debugger
4. Monitor variables in Watch Window
5. Get error reports
6. Get detailed statistics (how compiled code utilizes PIC MCU memory, hex Map, charts and more...).

It is legible, easy-tolerant, Procedural programming language, with sufficient power and flexibility needed for programming microcontrollers. [27].

3.3 Main control board program (PIC16F877 programming):

The main idea of the program is to read SMSs from the GSM module that has the SIM card or from Bluetooth handset as tones (later we will explain the Bluetooth commands) these SMSs from GSM module are processed by the program inside the microcontroller PIC16F877, and then the PIC CPU output the necessary command to the required end equipment as motor, light or the pump.

To do that, the microcontroller is connected with the GSM module through RS232 interface, to use this protocol, the micro basic program has a library called “write_USAT_text” and read_USAT_text” which are used to write and read commands to and from GSM module respectively, the GSM modem uses its AT command groups to deal with, this set of commands are used to program the GSM modem and the commands start normally with “AT” (means attention).In order for a compiler to execute these commands “AT” word must be written before each command for example the command ("AT+CMGR=1") written in the main board program means: read received message.

3.4 GSM modem SMSs:

In the program ,first it is important to define the variables such as: Bluetooth messages as byte, and SMS messages as string and so on, then the sub procedure “request” is called by the program, this sub procedure includes the program body responsible for sending and receiving commands and data from the GSM module using USART write and read commands, and as mentioned above, every command to the GSM modem must follow AT command, for example to read a message fromGSM modem the following command “**USART_WRITE_TEXT(AT+CMGR=1**), USART is a command used to Connect the microcontroller to the UART unit of the GSM modem, it stands for “Universal A synchronic Receive-Transmit” so the data and command exchange between GSM modem and the microcontroller is established by executing this command through RS232 interface .

The SMSs messages which are used as commands here are of three types:

1- The first message is ***L1on***, this message is standing for “light on” which means to switch the lamp on, and it is shown in the program as follows: **if((MSG1[0]="L")AND(MSG1[1]="1")AND(MSG1[2]="o")AND(MSG1[3]="n"))THEN 'L1on**

After executing this command messageshown in Appendix I by the microcontroller, it outputs a necessary signal through port A by the command “PORTA=$00” , then the address and the signal directed to the encoder which

supply these data to RF transmitter, which in sequence transmits it through antenna to be received by the required receiver (daughter board) which is in this case has the address “00” and the daughter board of address “00” is connected with our lamp through a relay contact which will be energized as soon as it receives the necessary power supply, in this case also the second LED of the main control board will lit, indicating that this command is directed to the daughter board of address “00” which means to lit the lamp, as mentioned before, the first LED is off when the message is received through GSM.

After that the Microcontroller PIC16F77 on the main board will be waiting for a feedback signal from the same daughter board indicating the status of the end equipment, which indicates that the lamp is on, and the microcontroller sends signal to the GSM modem to send a message “Light on” to the number **(0795464126)** which is my number, the sub procedure of the feedback status called: “**SUB PROCEDURE SEND_RESULT_TEST**” is shown in the main board program in Appendix I, as follow:

SUB PROCEDURE SEND_RESULT_TEST
USART_WRITE_TEXT("AT+CMGS=1”)
USART_WRITE(34)
USART_WRITE_TEXT("0795464126”)

This sub procedure sends the statuss of the end equipment to the GSM modem by the command “USART_WRITE_TEXT("AT+CMGS=1”).

2- The second message is ***L1off*** which stands for “light off” which will switch the lamp off and it is shown in the program as follows:

if((MSG1[0]="L")AND(MSG1[1]="1")AND(MSG1[2]="o")AND(MSG1[3]="f")AND(MSG1[4]="f"))THEN 'L1off.

It is the same as previous command, just this is decoded to switch the lamp off, it is of course uses the same address, and the second LED now will go off.

The same sub procedure is used for sending the status of the lamp “OFF”

The status of the lamp “off” is sent to the user with the same number using the same sub procedure as the previous commands.

3- The third command message is: ***D1on*** which stands for “door on” to open the door by starting its motor, it is shown in the program in Appendix I as follows:

if((MSG1[0]="D")AND(MSG1[1]="2")AND(MSG1[2]="o")AND(MSG1[3]="n"))THEN 'D2on.

When executing this command the address of the second daughter board "1011" and the start signal will be sent through the RF transmitter to open the door. Also the third LED will lit indicating that the command is sent to the door to open, this LED is lit by the command "**PORTB.6=1**"

4- The fourth command is the same as the third one just it is used to stop the door motor, for that the command part "ON" in the command message body is replaced by the word "OFF", and the command message will become as follow:

if((MSG1[0]="D")AND(MSG1[1]="2")AND(MSG1[2]="o")AND(MSG1[3]="f")AND(MSG1[4]="f"))THEN 'D2off

The address of the daughter board is the same (1011) and the same LED will go off in this case by the command "**portB.6=0".**

The feedback status is also sent to the same mobile number as SMS which indicates that the motor is running.

5- The fifth command message is ***P3ON*,** which stands for "pump on" that means to start the pump and it is shown in the program by the next command:

if((MSG1[0]="P")AND(MSG1[1]="3")AND(MSG1[2]="o")AND(MSG1[3]="n"))THEN 'P3on.

In this case the microcontroller output the necessary output signal to the third daughter board addresses by the command "port A=$03".then the fourth LED will go on, by the command "**PORTB.7=1** ".

The status of the pump motor is sent to the end user mobile phone as SMS which indicates the motor is running.

6- The sixth command is the same as fifth except that this command turns the pump off, and the word "off" replaces the word "on" in the command message body as follow:

if((MSG1[0]="P")AND(MSG1[1]="3")AND(MSG1[2]="o")AND(MSG1[3]="f")AND(MSG1[4]="f"))THEN *P3off*And the fourth LED will go off by the command**"PORTB.7=0"**

The status indicating that the motor is "off" is sent to the end user mobile phone as SMS.

3.5 Remote control using DTMF over Bluetooth:

When a person is at home, he or she doesn't need to use SMS messages to operate the end equipment (pump, door and light) instead a Bluetooth

technology can be used in this design, as shown in the hardware design in the block diagram of figure.1, and to use Bluetooth from a mobile phone. A Bluetooth handset is used, by connecting to the main control board, and can receives commands from a mobile phone and sent to the DTMF which converts these commands to suitable data to be processed by the PIC, this technology works as follow:

1- When ordering the first command - the light is required to be lit***L1on*** -a button "1" from the mobile phone is pressed, this button like other buttons within the phone key pad has its own tone with two frequencies, the two frequencies of the pressed button are transmitted , then these frequencies are received by the Bluetooth handset in the main control board, after that they are received by the IC **DTMF (Double tone modulation Frequency)** then a DTMF circuit converts this tone with two frequencies to digital data command with four digits, in the case of the first conversion it outputs to the PIC16F877 four digits (**0001**), then these four digits are transmitted to the **PIC 16F877,** the program checks every time the status of the first bit of port" C" if there is data received from Bluetooth by the command:

IF PORTC.4=1 THEN ' DATA RECIEVED FROM BLUTOOTH MODULE, if there is data the first LED will let indicating that Bluetooth is used for controlling the equipment by the command: **PORTB.4=1,** in case of GSM this LED will switch off as explained before.

2- The second command switches the light off, the light goes off when pressing key "2" at the mobile keypad, this key will is decoded inside DTMF circuit as (**0010**) as in the command "**CASE %00000010 '"2" *L1off*** then this code received by PIC16F877 and the light goes off again.
3- The third command through Bluetooth opens the door "D1_on",
   So when the key "3" is pressed from the mobile phone keypad, two frequencies are transmitted and received by the Bluetooth headset, then to the **DTMF,** which generates the code **(0011)** which is received by the PIC16F877 and the microcontroller outputs the necessary signal to activate the door motor.
4- The fourth command from Bluetooth switches the door motor off, when the key"4" in mobile phone keypad is pressed, the **DTMF** circuit generates a

code (**0100**) ,this code is received by the microcontroller, then processed and the door motor stops.

5- The fifth command starts the pump, so when a key"5" is pressed from the mobile keypad, a code (**0101**) is generated by **DTMF** circuit, then transmitted to the micro controller, the microcontroller output the necessary signal to start the pump.

6- The final command stops the pump, so when pressing the key"6" from mobile keypad, and this tone received by the **DTMF**, it generates a code (**0110**) which processed by the microcontroller and then stops the pump.

All of the above mentioned commands are executed by a program inside **PIC16F877** microcontroller and transmitted to the daughter boards with the appropriate addresses through RF technology.

The status of the end equipment is also sent to the end user mobile phone using GSM modem as SMS that indicates the Light is on or the pump motor is running or the door motor is running.

3.6 Daughter boards programming (PIC16F84A):

Using micro basic tools and mega basic program editor installed on Laptop a small program for each of the three daughter boards was typed and downloaded to the **PIC16F84** onthe daughter board, this program processes signals received from the main board via RF transceiver , and upon these data it energize the required relay, which through its contact supplies the necessary motor with voltage from external source, and sends the status of the end equipment received from the second contact "S2" of relay K2 shown in figure.13 to the main board through RF transceiver, The program is the same for each daughter board;but they are different in their addresses only, the program for each daughter board works as follow:

When the decoder receives the data from the RF transceiver, it checks the address of the daughter board (set physically by the local dip switches) in the received data frame, if the address matches the board address it receives the rest of data and transfers it to the PIC16F84A, then the PIC micro basic program executes the program as follow:

First the program assigns port "A" as output and port "B" for input from the decoder, then selects two cases: if the First case is "00001010" then it energizes the output relay K2, and in case of "00000101" it deenergizes the

output relay, when the relay is energized, the contact S1 of the relay K2 as shown in figure.13 is closed and passes power to the end equipment to start it, the second contact S2 is also closed and passes signal to the PIC16F84 indicating that the relay is energized and the end equipment is running, the PIC16F84 processes this signal and sends it to the main board indicating that the equipment is running, and the main board as explain before sends this status to the GSM modem and then it is sent as SMS to the end user mobile phone with number such as**"0795464126"**or any other number provided that the software is slightly changed to accommodate this new phone number.

Chapter Four
Results and discussion

4.1 Receiving from GSM:

1- **Switching Light on: this action remotely switches the light on by GSM technology.**

From the mobile phone a short message(SMS) ***L1ON*** has been sent to the GSM modem equipped with its SIM card connected to the main control board, after the message was received by the modem, the micro controller (PIC16F877) in the main control board received this SMS from the modem, then first LED at the main control board stayed in “off” state which indicates that, the GSM transmission is in operation, the message was processed by the microcontroller program, then an action was taken to send the necessary command to the daughter board with address (00) which is connected to the lamp by the contact **S1** of the relay K2 as discussed before , and switches the light on, after that a feedback message “**Light 1 is on**” was received to the mobile phone indicating that the light is on, this daughter board is allocated away from the main control board, and RF wireless technology is used to communicate with these daughter boards, it has an LED which switches on and off according to its operation.Figure.18 shows the SMS text to switch light on, and its feedback status messageis shown in Figure.19



Fig. (17)
SMS Text (*L1on*)



Fig (18)
SMS (Light On)

The delay time for message sending measured as follows:

$$Tdelay = L1on - (Light\ is\ on) \qquad (2)$$

$$= 22:37:00 - 22:36:50 = 10\ seconds$$

Where: (L1on) is sending time.

:(Light is on) is feedback message arriving time.

Knowing that this delay time is composed of the following:

1- GSM network delay.
2- Main board processing time.
3- RF transmission delay (time taken for transmission the signal from the main board to the daughter board)
4- Daughter board processing time.

2- Switching Light off:

It is the same procedure as switching light on, but here the command***L1off*** has been sent to the same daughter board with address (00) and switched light off , afeedback SMS was received by the mobile phone of the end user indicating that the light is turned off as shown in Figure.20 below.



Fig. (19) “Light off”

1- Starting the Door Motor:

SMS message from the mobile phone***D2on*** has been sent to the daughter board with address (01), the motor was started and a feedback SMS message was received which indicated the status that the motor is running as shown in Figure.21.



Fig. (20)
"Door on"

1- Stopping the Door Motor:

SMS message ***D2off*** has been sent to the daughter board with the same address as previous one (01), the motor stopped and a feedback SMS message was received by the mobile phone indicating that the motor stopped as shown in Figure.22.



Fig. (21)
SMS (Door Off)

2- Starting the Pump.

SMS message ***P3ON*** has been sent to the GSM daughter board with address (02), the pump motor is started normally, and a feedback SMS message was received by the mobile phone indicating that, the pump is running as shown in Figure.23.



Fig. (22)
SMS (Pump On)

3- Stopping the Pump:

SMS message ***P3off*** has been sent to the GSM daughter board with address (02), the pump motor stopped, and a feedback SMS message was received by the mobile phone indicating that, the pump stopped as shown in Figure 24.



Fig. (23)

SMS (Pump Off)

4.2 Receiving from DTMF over Bluetooth:

1- Switching light on:

Operation of the system can be made fromthe mobile phone, when itis near to the main control board (in the range of Bluetooth distance of around 50 meters) press of key “1” from the phone keypad activates the first LED of the main control card and turnsit on, which indicates that the control is activated by Bluetooth, then the second LED switched to status “on” also indicating that the command is to switch the light on, after that, the microcontroller sends the necessary command to the daughter board of address (00) to switch the light on, the LED of the lamp daughter board is turned on, indicating that the daughter board received the order to let the lamp on, and at the same time the contact relay was energized and pass the power supply to the lamp and turn it on then feedback SMS was received by the mobile phone using GSM network which reported that the light is on.

1- Switching light off:
   The same daughter board is used with the address (00), but when the key”2” is pressed from the phone keypad, the light switched off, and a feedback message is received indicating that the light is off.
2- Starting the door motor:
   Press of key“3” from the mobile keypad started the motor connected to the daughter board at address (01), and a feedback SMS is received by the mobile phone indicated that the door motor is running.
3- Stopping the door motor:
   Press of key “4” from the mobile keypad stopped the motor connected to the daughter board at address (01), and a feedback SMS is received by the mobile phone indicated that the door motor is stopped.
4- Starting the pump:

Press of key “5” from the mobile keypad starts the pump motor connected to the daughter board of address (02), and a feedback SMS is received by the mobile phone indicated that the pump motor is running.

6- Stopping the pump:

Press of key “6” from the mobile keypad stops the pump motor connected to the daughter board at address (02), and a feedback SMS is received by the mobile phone indicated that the pump motor is stopped.

Comparing our work with others, such as the work done by R.Chuta, D.Sonowal and S.Sharmatiteled as “Remote Household Appliance control system uses GSM”, our project proved to be better and more useful for handicapped people for the following reasons:

1- Our design controls devices located away from each other, without needs for wires between them and the main control board, RF technology is used instead, this required designing a small board called “daughter board” for each device, which saves on cost.
2- In this design when the user is at home, a Bluetooth technology can be used to control the devices. So this increase the hardware components.
3- Our design uses GSM modem instead of a mobile phone at the receiving end.

Chapter Five
Conclusions and future work

5.1 Conclusion

In this thesis, a good remote control system has been developed and implemented, this system negatively privileged people or any other person to remotely control distant applications, in this project, the remote control is achieved using GSM, and for closely placed devices, Bluetooth technology was used.

The system was tested, and proved working normally, and any person using mobile phone can remotely control home equipment through GSM (global system) by sending one of the command messages specified in the "software" or when the person is near to the device, the use of Bluetooth technology is preferred.

The feedback used was of major advance over other people achievement, it enabled us to be sure of wither the appliance has responded correctly to the issued commands or not. A mathematical formula has been introduced which specified the delay time for the system.

The system is expendable, so any equipment can be added to it by increasing the daughter boards and adding some necessary commands to the code like adding more SMSs.

The project is wireless, since the connection of the main board to the daughter boards is based on RF technology ,up to 150 meters, this technology works at frequency about 434 MHz.

5.2 Future work:

Many options for future work can be studied and implemented; here are some of these options:

1- As long as we use RF technology between the main board and the daughter boards, more equipment can be added to the project by little modification in the software program and adding more daughter boards with the same design.
2- The software can be modified to accept analogue signals by installing several sensors as temperature, pressure…etc.
3- A use of the internet can be an option for communication system, along with GSM in case of GSM network failure.
4- Dual SIM card can be implemented to remotely control the system, and in case of one network failure the other can be used, this will increase the system availability.

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Appendix I
Main Migabasic program Code

```
program EngAli_GSM_Main

DIM M AS STRING [10[
DIM X, MMSG, BLUTOOTH, READ_TEST AS BYTE
DIM I AS WORD
DIM MSG AS STRING [50[
DIM MSG1 AS STRING [20[


SUB PROCEDURE REQUIST
USART_WRITE_TEXT ("AT+CMGR=1")
USART_WRITE(13)
USART_WRITE(10)
DELAY_MS(100)
X=USART_READ
END SUB

SUB PROCEDURE DEL_MSG
USART_WRITE_TEXT ("AT+CMGD=1")
USART_WRITE(13)
USART_WRITE(10)
DELAY_MS(100)
END SUB
SUB PROCEDURE SEND_RESULT_TEST
USART_WRITE_TEXT("AT+CMGS=1")
USART_WRITE(34)
USART_WRITE_TEXT("0795464126")
USART_WRITE(34)
USART_WRITE(13)
USART_WRITE(10)
DELAY_MS(1000)

USART_WRITE(34)
USART_WRITE_TEXT(MSG)
USART_WRITE(34)
DELAY_MS(100)
USART_WRITE(26)    'CTRL Z
DELAY_MS(4000)


END SUB
Main:
TRISA=0
ADCON1=$06
PORTA=0   'RA0 .. RA3 ARE ADDRESS OUTPUT
TRISC.0=0 'DATA O/P WIRELESS
TRISC.1=0 'DATA O/P WIRELESS
TRISC.2=0 'DATA O/P WIRELESS
TRISC.3=0 'DATA O/P WIRELESS
TRISD.4=1 'DATA I/P WIRELESS
TRISD.5=1 'DATA I/P WIRELESS
```

```
TRISD.6=1 'DATA I/P WIRELESS
TRISD.7=1 'DATA I/P WIRELESS

READ_TEST=0
USART_INIT (9600)' INIT THE GSM COMMUNICATION
TRISB=0 ' LEDS INDECATION FOR WIRELESS TRANSMITTER
TRISD.0=1 ' DTMF DATA-0
TRISD.1=1 ' DTMF DATA-1
TRISD.2=1 ' DTMF DATA-2
TRISD.3=1 ' DTMF DATA-3
TRISC.4=1 ' DTMF SIGNAL RECIEVED
M"*"=
TRISB.0=1
PORTB=0
TRISA.5=0  ' FOR TE
PORTA.5=0  ' ENABLE TX

'CONFIGURATION THE GSM WITH PIC
USART_WRITE_TEXT("AT”)
USART_WRITE(13)
USART_WRITE(10)
DELAY_MS(2000)

USART_WRITE_TEXT ("AT+CMGF=1”)
USART_WRITE(13)
USART_WRITE(10)
DELAY_MS(1000)


****'
DEL_MSG
*****'

RUN:

'PORTA=0 'SET ADDRESS = 0
'CHECK THE DATA FROM BLUTOOTH
IF PORTC.4=1 THEN ' DATA RECIEVED FROM BLUTOOTH MODULE
BLUETOOTH:
PORTB.4=1
BLUTOOTH=(PORTD)AND ($0F)
SELECT CASE BLUTOOTH
CASE %00000001   '"1" L1-on
PORTA=$00
DELAY_MS(20)(
PORTB.5=1
PORTC.0=1
PORTC.1=1
PORTC.2=1
PORTC.3=1
CASE %00000010 ‘"2" L1-OFF
```

```
PORTA=$00
DELAY_MS (200)
PORTB.5=0
PORTC.0=0
PORTC.1=0
PORTC.2=0
PORTC.3=0
CASE %00000011   '"3" D2-on
PORTA=$01
DELAY_MS (200)
PORTB.6=1
PORTC.0=1
PORTC.1=1
PORTC.2=1
PORTC.3=1
CASE %00000100 ‘"4" D2-OFF
PORTA=$01
DELAY_MS (200)
PORTB.6=0
PORTC.0=0
PORTC.1=0
PORTC.2=0
PORTC.3=0
CASE %00000101   '"5" P3-on
PORTA=$02
DELAY_MS (200)
PORTB.7=1
PORTC.0=1
PORTC.1=1
PORTC.2=1
PORTC.3=1
CASE %00000110 ‘"6" P3-OFF
PORTA=$02
DELAY_MS (200)
PORTB.7=0
PORTC.0=0
PORTC.1=0
PORTC.2=0
PORTC.3=0
END SELECT
END IF
 ****'READING MSG****

REQUIST
FOR I=0 TO 40000
IF PORTC.4=1 THEN GOTO BLUETOOTH END IF' DATA RECIEVED FROM
BLUTOOTH MODULE
X=USART_READ
IF (X=42) THEN
GOTO ACTION
END IF
```

```
NEXT I
GOTO RUN
ACTION:
PORTB.4=0
USART_READ_TEXT (MSG1, M)
DELAY_MS (100)

if((MSG1[0]="L")AND(MSG1[1]="1")AND(MSG1[2]="o")AND(MSG1[3]="n"))THEN
'L1on
PORTA.5=0 ' ENABLE TX IN ENCODER
PORTA=$00
DELAY_MS (200)
PORTB.5=1
PORTC.0=1
PORTC.1=1
PORTC.2=1
PORTC.3=1
DEL_MSG
END IF
if((MSG1[0]="L")AND(MSG1[1]="1")AND(MSG1[2]="o")AND(MSG1[3]="f")AND(MSG1
[4]="f"))THEN  'L1off
PORTA.5=0 ' ENABLE TX IN ENCODER
PORTA=$00
DELAY_MS (200)
PORTB.5=0
PORTC.0=0
PORTC.1=0
PORTC.2=0
PORTC.3=0
DEL_MSG
END IF
 *****'  TEST L1*****
if((MSG1[0]="L")AND(MSG1[1]="1")AND(MSG1[2]="t")AND(MSG1[3]="s")AND(MSG1
[3]="t"))THEN  'L1tst
PORTA=$00
DELAY_MS (200)
PORTB.5=1
PORTC.0=1
PORTC.1=0
PORTC.2=0
PORTC.3=1
DEL_MSG
DELAY_MS (1000)
PORTA.5=1 ' DISABLE TX IN ENCODER
 ***'    WAITING TO READ FROM DOUGHTER BOARD
READ_TEST=PORTD AND $F0
WHILE READ_TEST=0
READ_TEST=PORTD AND $F0
WEND
IF READ_TEST=%10010000 THEN 'L1 IS ON
MSG="LIGHT 1 IS ON"
```

```
SEND_RESULT_TEST
END IF
IF READ_TEST=%01100000 THEN 'L1 IS OFF
MSG="LIGHT 1 IS OFF"
SEND_RESULT_TEST
END IF
END IF
 *****'  END TEST L1*****
if((MSG1[0]="D")AND(MSG1[1]="2")AND(MSG1[2]="o")AND(MSG1[3]="n"))THEN
'D2on
PORTA.5=0 ' ENABLE TX IN ENCODER
PORTA=$01
DELAY_MS(200)
PORTB.6=1
PORTC.0=1
PORTC.1=1
PORTC.2=1
PORTC.3=1
DEL_MSG
END IF
if((MSG1[0]="D")AND(MSG1[1]="2")AND(MSG1[2]="o")AND(MSG1[3]="f")AND(MSG1
[4]="f"))THEN  'D2off
PORTA.5=0 ' ENABLE TX IN ENCODER
PORTA=$01
DELAY_MS(200)
PORTB.6=0
PORTC.0=0
PORTC.1=0
PORTC.2=0
PORTC.3=0
DEL_MSG
END IF
 *****'  TEST D2*****
if((MSG1[0]="D")AND(MSG1[1]="2")AND(MSG1[2]="t")AND(MSG1[3]="s")AND(MSG1
[3]="t"))THEN  'D2tst
PORTA=$01
DELAY_MS(20)
PORTB.6=1
PORTC.0=1
PORTC.1=0
PORTC.2=0
PORTC.3=1
DEL_MSG
DELAY_MS(1000)
PORTA.5=1 ' DISABLE TX IN ENCODER
 ***'    WAITING TO READ FROM DOUGHTER BOARD
READ_TEST=PORTD AND $F0
WHILE READ_TEST=0
READ_TEST=PORTD AND $F0
WEND
IF READ_TEST=%10010000 THEN 'D2 IS ON
```

```
MSG="DOOR 2 IS ON"
SEND_RESULT_TEST
END IF
IF READ_TEST=%01100000 THEN 'D2 IS OFF
MSG="DOOR 2 IS OFF"
SEND_RESULT_TEST
END IF
END IF
 *****'  END TEST D2*****
if((MSG1[0]="P")AND(MSG1[1]="3")AND(MSG1[2]="o")AND(MSG1[3]="n"))THEN
'P3on
PORTA.5=0 ' ENABLE TX IN ENCODER
PORTA=$02
DELAY_MS(200)
PORTB.7=1
PORTC.0=1
PORTC.1=1
PORTC.2=1
PORTC.3=1
DEL_MSG
END IF
if((MSG1[0]="P")AND(MSG1[1]="3")AND(MSG1[2]="o")AND(MSG1[3]="f")AND(MSG1
[4]="f"))THEN  'P3off
PORTA.5=0 ' ENABLE TX IN ENCODER
PORTA=$02
DELAY_MS(200)
PORTB.7=0
PORTC.0=0
PORTC.1=0
PORTC.2=0
PORTC.3=0
DEL_MSG
END IF
 *****'  TEST P3*****
if((MSG1[0]="P")AND(MSG1[1]="3")AND(MSG1[2]="t")AND(MSG1[3]="s")AND(MSG1
[3]="t"))THEN  'P3tst
PORTA=$01
DELAY_MS(200)
PORTB.7=1
PORTC.0=1
PORTC.1=0
PORTC.2=0
PORTC.3=1
DEL_MSG
DELAY_MS(1000)
PORTA.5=1 ' DISABLE TX IN ENCODER
 ***'    WAITING TO READ FROM DOUGHTER BOARD
READ_TEST=PORTD AND $F0
WHILE READ_TEST=0
READ_TEST=PORTD AND $F0
WEND
```

```
IF READ_TEST=%10010000 THEN 'P3 IS ON
MSG="PUMB 3 IS ON"
SEND_RESULT_TEST
END IF
IF READ_TEST=%01100000 THEN 'P3 IS OFF
MSG="PUMB 3 IS OFF"
SEND_RESULT_TEST
END IF
END IF
 *****'  END TEST P3*****
DEL_MSG ‘DELETE MSG IF IT IS NOT COMPATABLE WITH OUR COMMANDS
GOTO RUN
END.
```

programEngAli_GSM_Doughter_change

```
DIM DATA  AS BYTE
main:
TRISA.0=0          ' FOR RELAY OUTPUT
'INPUT  FROM  HT12D (PORTB<0:3>) / OUTPUT TO HT12E (PORTB<4:7:>)
TRISB=$0F
PORTB=0
TRISA.2=1   ' FOR FEEDBACK SIGNAL
TRISA.3=0   'FOR ENABLE OF HT12E
PORTA.3=1   'DEFULT DISABLE TE OF HT12E
RUN:
DATA=(PORTB)AND ($0F)
SELECT CASE  DATA
CASE %00001010   'RELAY-on
    PORTA.0=1
CASE %00000101  'RELAY-OFF
    PORTA.0=0
CASE %00001001  'CHECK IF RELAY ON OR OF
  IF PORTA.2=0 THEN  'IT'S ON
     PORTA.3=0    'ENABLE TE OG HT12E
     PORTB=10010000
     DELAY_MS(1000)
     PORTA.3=1    'DISABLE TE OG HT12E
  ELSE             'IT'S OFF
     PORTA.3=0    'ENABLE TE OG HT12E
     PORTB=01100000
     DELAY_MS(1000)
     PORTA.3=1    'DISABLE TE OG HT12E
  END IF
END SELECT
GOTO RUN
END.
```

Appendix II
Voltage regulator datasheet

KEC
KOREA ELECTRONICS CO.,LTD.

SEMICONDUCTOR
TECHNICAL DATA

KIA7805AP/API~ KIA7824AP/API

BIPOLAR LINEAR INTEGRATED CIRCUIT

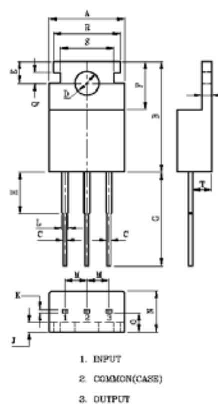
THREE TERMINAL POSITIVE VOLTAGE REGULATORS
5V, 6V, 8V, 9V, 10V, 12V, 15V, 18V, 20V, 24V.

FEATURES

- Suitable for C-MOS, TTL, the Other Digital IC's Power Supply.
- Internal Thermal Overload Protection.
- Internal Short Circuit Current Limiting.
- Output Current in Excess of 1A.
- Satisfies IEC-65 Specification. (International Electronical Commission).

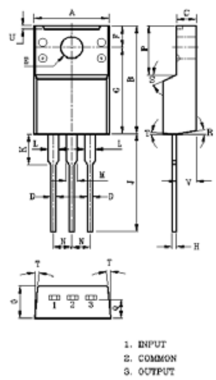
MAXIMUM RATINGS (Ta=25℃)

CHARACTERISTIC		SYMBOL	RATING	UNIT
Input Voltage	KIA7805AP/API~ KIA7815AP/API	V_{IN}	35	V
	KIA7818AP/API~ KIA7824AP/API		40	
Power Dissipation (Tc=25℃)		P_D	20.8	W
Power Dissipation (Without Heatsink)	KIA7805API~ KIA7824API	P_D	2.0	W
Operating Junction Temperature		T_j	-30~150	℃
Storage Temperature		T_{stg}	-55~150	℃



DIM	MILLIMETERS
A	10.30 MAX
B	15.30 MAX
C	0.85
D	ϕ3.60±0.20
E	3.00
F	6.70 MAX
G	13.60±0.50
H	5.60 MAX
J	1.37 MAX
K	0.50
L	1.60 MAX
M	2.54
N	4.70 MAX
O	2.60
P	1.50 MAX
Q	1.50
R	9.50±0.20
S	8.00±0.20
T	2.90 MAX

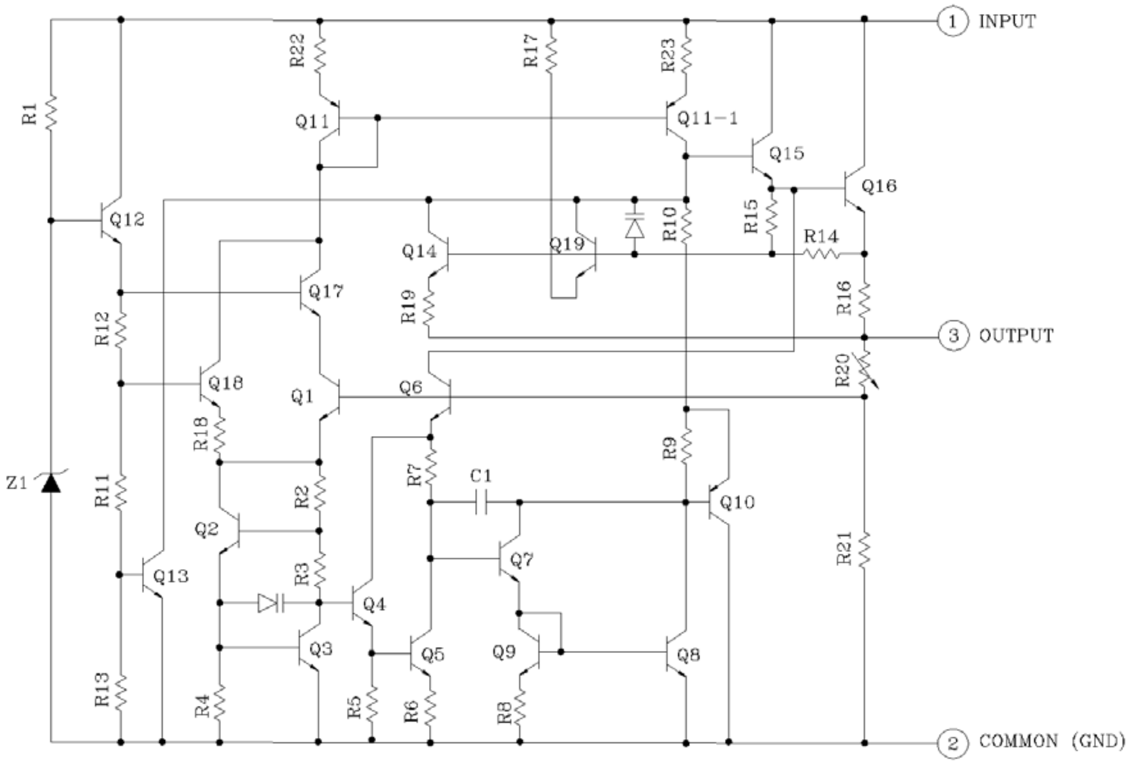
TO-220AB



DIM	MILLIMETERS
A	10.30 MAX
B	15.30 MAX
C	2.70±0.30
D	0.85 MAX
E	ϕ3.20±0.20
F	3.00±0.30
G	12.30 MAX
H	0.75 MAX
J	13.60±0.50
K	3.90 MAX
L	1.20
M	1.30
N	2.54
O	4.50±0.20
P	6.80
Q	2.60±0.20
R	10°
S	25°
T	5°
U	0.5
V	2.60±0.15

TO-220IS

EQUIVALENT CIRCUIT

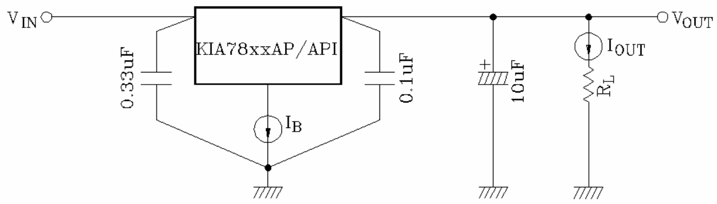


KIA7805AP/API

ELECTRICAL CHARACTERISTICS (V_{IN}=10V, I_{OUT}=500mA, 0℃≦T_j≦125℃)

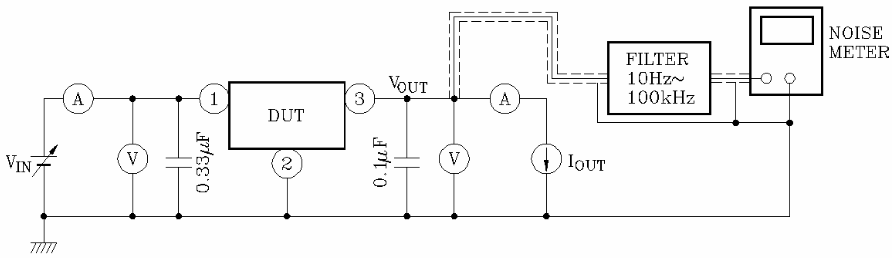
CHARACTERISTIC	SYMBOL	TEST CIRCUIT	TEST CONDITION		MIN.	TYP.	MAX.	UNIT
Output Voltage	V_{OUT}	1	T_j=25℃, I_{OUT}=100mA		4.8	5.0	5.2	V
Input Regulation	Reg line	1	T_j=25℃	7.0V≦V_{IN}≦25V	-	3	100	mV
				8.0V≦V_{IN}≦12V	-	1	50	
Load Regulation	Reg load	1	T_j=25℃	5mA≦I_{OUT}≦1.4A	-	15	100	mV
				250mA≦I_{OUT}≦750mA	-	5	50	
Output Voltage	V_{OUT}	1	7.0V≦V_{IN}≦20V 5.0mA≦I_{OUT}≦1.0A, Po≦15W		4.75	-	5.25	V
Quiescent Current	I_B	1	T_j=25℃, I_{OUT}=5mA		-	4.2	8.0	mA
Quiescent Current Change	ΔI_B	1	7.0V≦V_{IN}≦25V		-	-	1.3	mA
Output Noise Voltage	V_{NO}	1	Ta=25℃, 10Hz≦f≦100kHz I_{OUT}=50mA		-	50	-	μV_{rms}
Ripple Rejection Ratio	RR	1	f=120Hz, 8.0V≦V_{IN}≦18V, I_{OUT}=50mA, T_j=25℃		62	78	-	dB
Dropout Voltage	V_D	1	I_{OUT}=1.0A, T_j=25℃		-	2.0	-	V
Short Circuit Current Limit	I_{SC}	1	T_j=25℃		-	1.6	-	A
Average Temperature Coefficient of Output Voltage	TC_{VO}	1	I_{OUT}=5mA, 0℃≦T_j≦125℃		-	-0.6	-	mV/℃

TEST CIRCUIT1/STANDARD APPLICATION CIRCUIT

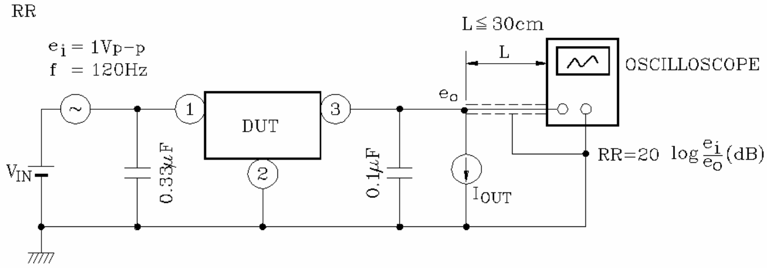


TEST CIRCUIT

1. V_{OUT} , Reg · line , Reg · load , V_{OUT} , I_B , ΔI_B , V_{NO} , ΔV_{OUT} /Δt , | $V_{IN} - V_{OUT}$ | , TC_{VO}



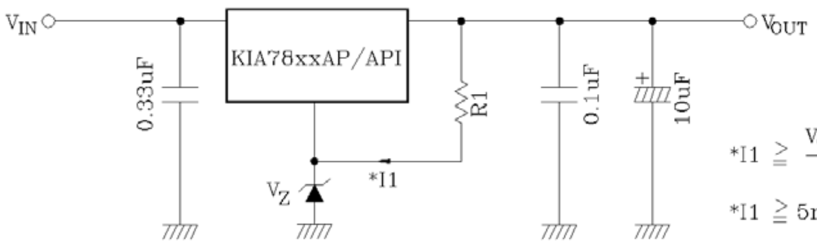
2. RR



APPLICATION CIRCUIT

(1) VOLTAGE BOOST REGULATOR

(a) Voltage boost by use of zener diode

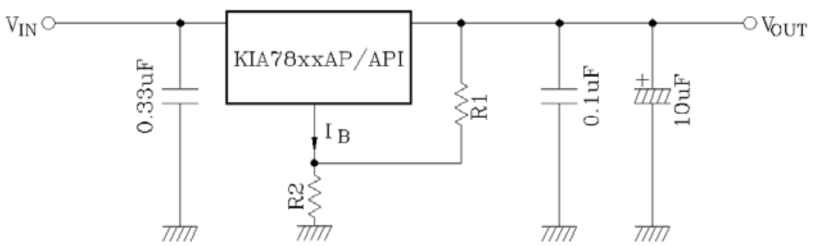


$*I1 \geqq \frac{V_{OUT(IC)}}{R1}$

$*I1 \geqq 5mA$

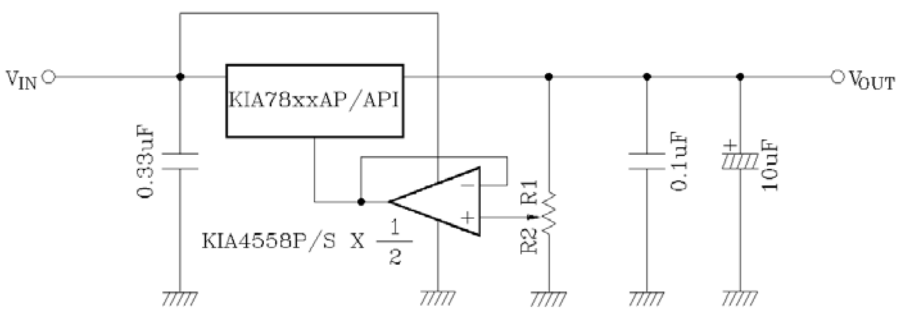
$V_{OUT} = V_{OUT(IC)} + V_Z$

(b) Voltage boost by use of resistor



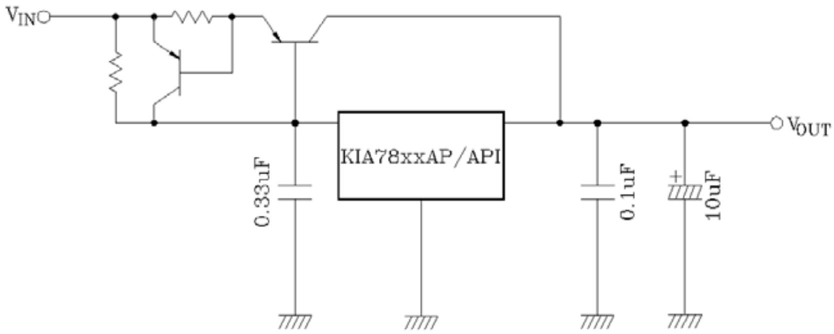
$$V_{OUT} = V_{OUT(IC)} \left(1 + \frac{R2}{R1}\right) + R2 \cdot I_B$$

(c) Adjustable output regulator



$$V_{OUT} = V_{OUT(IC)} \left(1 + \frac{R2}{R1}\right)$$

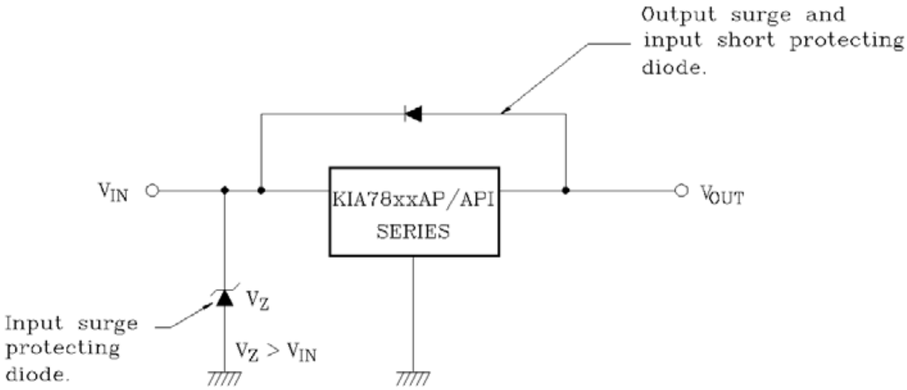
(2) CURRENT BOOST REGULATOR



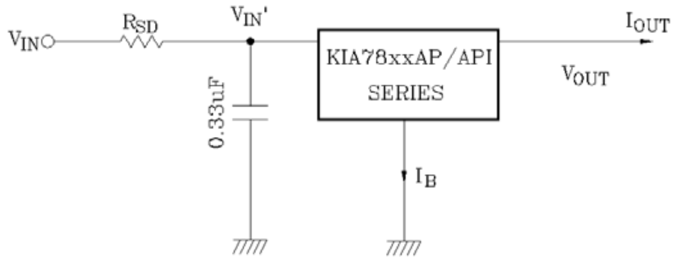
PRECAUTIONS ON APPLICATION

(1) In regard to GND, be careful not to apply a negative voltage to the input/ output terminal. Further, special care is necessary in case of a voltage boost application.

(2) When a surge voltage exceeding maximum rating is applied to the input terminal or when a voltage in excess of the input terminal voltage is applied to the output terminal, the circuit may be destroyed.
Specially, in the latter case, great care is necessary
Further, if the input terminal shorts to GND in a state of normal operation, the output terminal voltage becomes higher than the input voltage (GND potential), and the electric charge of a chemical capacitor connected to the output terminal flows into the input side, which may cause the destruction of circuit.
In these cases, take such steps as a zener diode and a general silicon diode are connected to the circuit, as shown in the following figure.



(3) When the input voltage is too high, the power dissipation of three terminal regulator increase because of series regulator, so that the junction temperature rises.
In such a case, it is recommended to reduce the power dissipation by inserting the power limiting resistor R_{SD} in the input terminal, and to reduce the junction temperature as a result.



The power dissipation P_D of IC is expressed in the following equation.

$$P_D = (V_{IN}' - V_{OUT}) \cdot I_{OUT} + V_{IN}' \cdot I_B$$

If V_{IN}' is reduced below the lowest voltage necessary for the IC, the parasitic oscillation will be caused according to circumstances.
In determining the resistance value of R_{SD}, design with margin should be made by making reference to the following equation.

$$R_{SD} < \frac{V_{IN} - V_{IN}'}{I_{OUT} + I_B}$$

(4) Connect the input terminal and GND, and the output terminal and GND, by capacitor respectively. The capacitances should be determined experimentally because they depend on printed patterns. In particular, adequate investigation should be made so that there is no problem even at time of high or low temperature.

(5) Installation of IC for power supply
For obtaining high reliability on the heat sink design of the regulator IC, it is generally required to derate more than 20% of maximum junction temperature (T_j MAX.) Further, full consideration should be given to the installation of IC to the heat sink.

(a) Heat sink design
The thermal resistance of IC itself is required from the viewpoint of the design of elements, but the thermal resistance from the IC package to the open air varies with the contact thermal resistance.
Table 1 shows how much the value of the contact thermal resistance ($\theta_C + \theta_S$) is changed by insulating sheet (mica) and heat sink grease.

TABLE 1. UNIT: ℃/W

PACKAGE	MODEL NO.	TORQUE	MICA	$\theta_C + \theta_S$
TO-220AB	KIA78xxAP	6kg·cm	Not Provided	0.3~0.5(1.5~2.0)
			Provided	2.0~2.5(4.0~6.0)

The figures given in parentheses denote the values at time of no grease.
The package of regulator IC serves as GND, therefore, usually use the value at time of "no mica"

(b) Silicon grease

When a circuit not exceeding maximum rating is designed, it is to be desired that the grease should be used if possible. If it is required that the contact thermal resistance is reduced from the view-point of the circuit design, It is recommended that the following methods be adopted.

A: Use Thercon (Fuji High Polymer Kogyo K.K)
B: Use SC101 (Torei Silicon) or G-640 (GE), if grease is used.

(c) Torque

When installing IC on a heat sink or the like, tighten the IC with the torque of less than the rated value. If it is tightened with the torque in excess of the rated value, sometimes the internal elements of the IC are adversely affected. Therefore, great care should be given to the installing operation. Further, if polycarbonate screws are used, the torque causes a change with the passage of time, which may lessen the effect of radiation.

(6) IEC (International Electronical Commission)-65 Specification.

(a) IEC (International Electronical Commission)-65 is the standard, parts testing method, machinery and tolls (used in connecting main power directly and indirectly) Which are used at home and general building. The purpose of the above standard is not to breaking out the risk which is related to an electric shock, a heating, a fire and the damage of surrounding parts in the case of normal or abnormal operating.

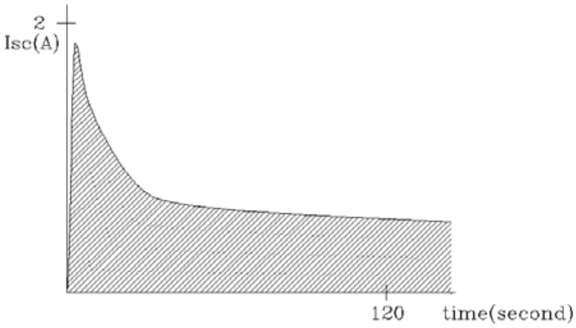
(b) In case temperature is limited by temperature overheating prevention device, fuse or the operation of fuse resistor

One must calculate the temperature of PCB substrate in 2 minute.

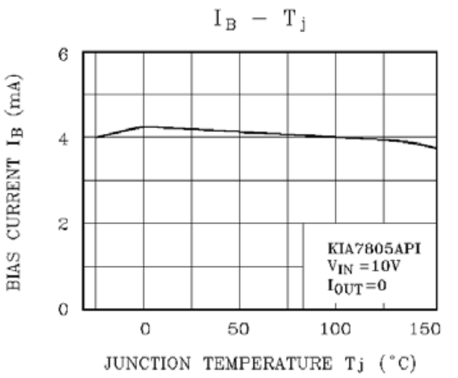
$\Delta T \leq 110°C$ regulated

$\Delta T = T$(The PCB substrate temperature in 2 minute) $- Ta$(Ambient temperature)

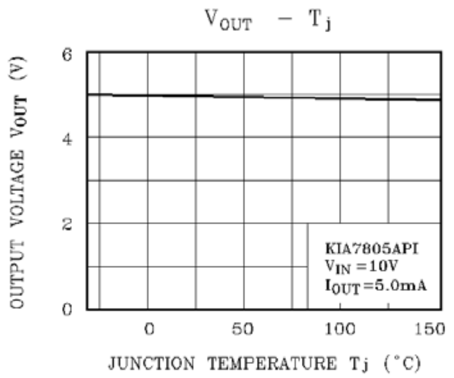
(c) Graph



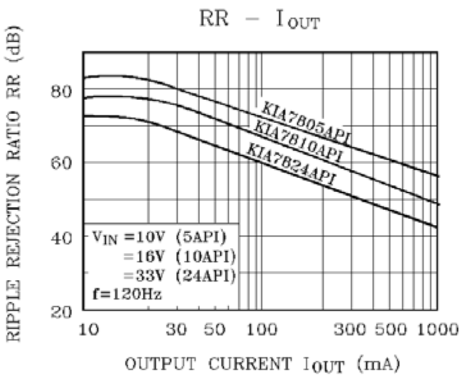
As the territory of the deviant line appear by the heat, as the area is wider, T(The PCB substrate temperature in 2 minute) is becoming high.



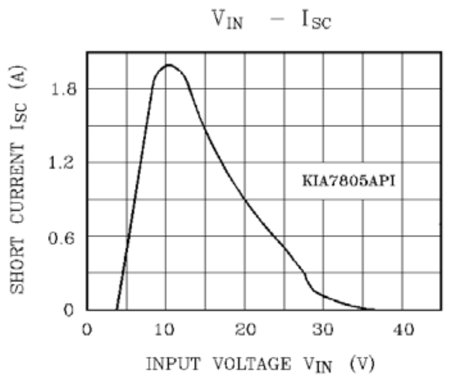
IB – Tj
BIAS CURRENT IB (mA)
JUNCTION TEMPERATURE Tj (°C)
KIA7805API
VIN =10V
IOUT=0



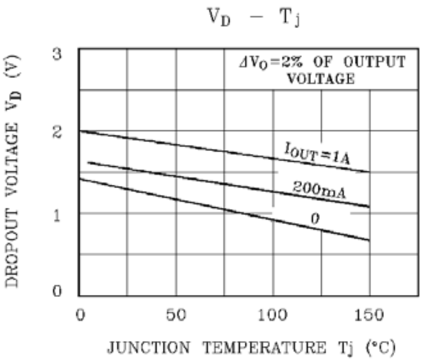
VOUT – Tj
OUTPUT VOLTAGE VOUT (V)
JUNCTION TEMPERATURE Tj (°C)
KIA7805API
VIN =10V
IOUT=5.0mA



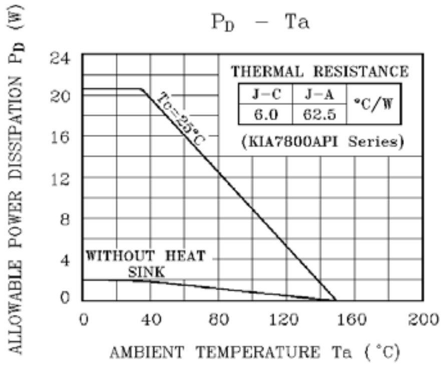
RR – IOUT
RIPPLE REJECTION RATIO RR (dB)
OUTPUT CURRENT IOUT (mA)
KIA7805API
KIA7810API
KIA7824API
VIN =10V (5API)
=16V (10API)
=33V (24API)
f=120Hz



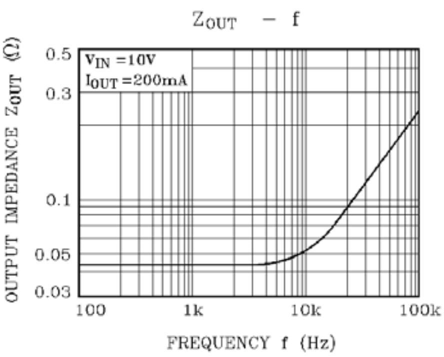
VIN – ISC
SHORT CURRENT ISC (A)
INPUT VOLTAGE VIN (V)
KIA7805API



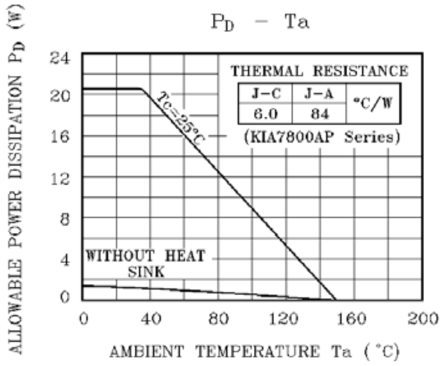
VD − Tj
ΔVO=2% OF OUTPUT VOLTAGE
IOUT=1A
200mA
0
DROPOUT VOLTAGE VD (V)
JUNCTION TEMPERATURE Tj (°C)



PD − Ta
THERMAL RESISTANCE
J−C 6.0
J−A 62.5
°C/W
(KIA7800API Series)
Tc=25°C
WITHOUT HEAT SINK
ALLOWABLE POWER DISSIPATION PD (W)
AMBIENT TEMPERATURE Ta (°C)



ZOUT − f
VIN =10V
IOUT =200mA
OUTPUT IMPEDANCE ZOUT (Ω)
FREQUENCY f (Hz)



PD − Ta
THERMAL RESISTANCE
J−C 6.0
J−A 84
°C/W
(KIA7800AP Series)
Tc=25°C
WITHOUT HEAT SINK
ALLOWABLE POWER DISSIPATION PD (W)
AMBIENT TEMPERATURE Ta (°C)

Appendix III
RF Encoder HT datasheet

HOLTEK

HT12A/HT12E
2^{12} Series of Encoders

Features

- Operating voltage
  - 2.4V~5V for the HT12A
  - 2.4V~12V for the HT12E
- Low power and high noise immunity CMOS technology
- Low standby current: 0.1μA (typ.) at V_{DD}=5V
- HT12A with a 38kHz carrier for infrared transmission medium
- Minimum transmission word
  - Four words for the HT12E
  - One word for the HT12A
- Built-in oscillator needs only 5% resistor
- Data code has positive polarity
- Minimal external components
- Pair with Holtek's 2^{12} series of decoders
- 18-pin DIP, 20-pin SOP package

Applications

- Burglar alarm system
- Smoke and fire alarm system
- Garage door controllers
- Car door controllers
- Car alarm system
- Security system
- Cordless telephones
- Other remote control systems

General Description

The 2^{12} encoders are a series of CMOS LSIs for remote control system applications. They are capable of encoding information which consists of N address bits and 12–N data bits. Each address/data input can be set to one of the two logic states. The programmed addresses/data are transmitted together with the header bits via an RF or an infrared transmission medium upon receipt of a trigger signal. The capability to select a $\overline{TE}$ trigger on the HT12E or a DATA trigger on the HT12A further enhances the application flexibility of the 2^{12} series of encoders. The HT12A additionally provides a 38kHz carrier for infrared systems.

Selection Table

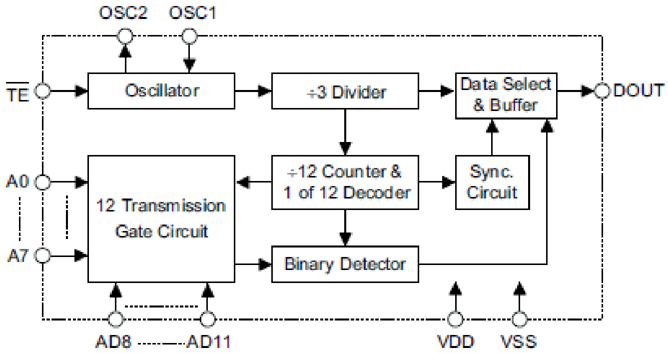
Function / Part No.	Address No.	Address/ Data No.	Data No.	Oscillator	Trigger	Carrier Output	Negative Polarity	Package
HT12A	8	0	4	455kHz resonator	D8~D11	38kHz	No	18DIP, 20SOP
HT12E	8	4	0	RC oscillator	$\overline{TE}$	No	No	18DIP, 20SOP

Note: Address/Data represents pins that can be either address or data according to the application requirement.

Block Diagram

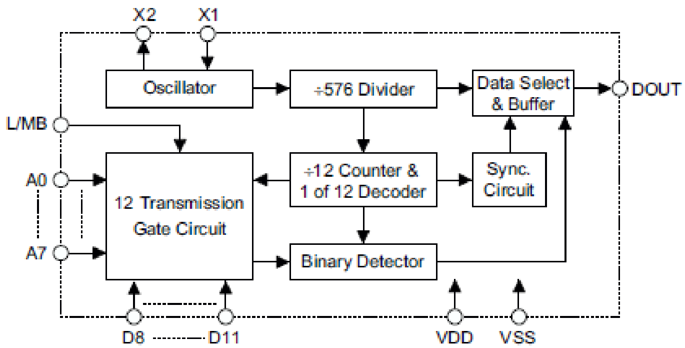
TE Trigger

HT12E



DATA Trigger

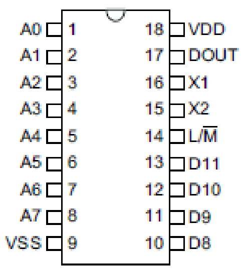
HT12A



Note: The address data pins are available in various combinations (refer to the address/data table).

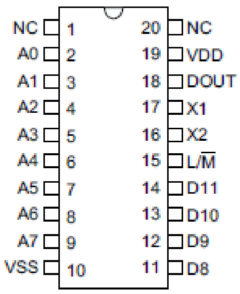
Pin Assignment

8-Address 4-Data



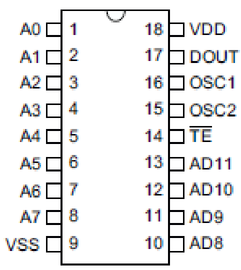
HT12A –18 DIP-A

8-Address 4-Data



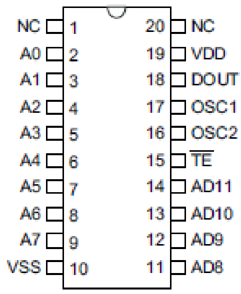
HT12A –20 SOP-A

8-Address 4-Address/Data



HT12E –18 DIP-A

8-Address 4-Address/Data



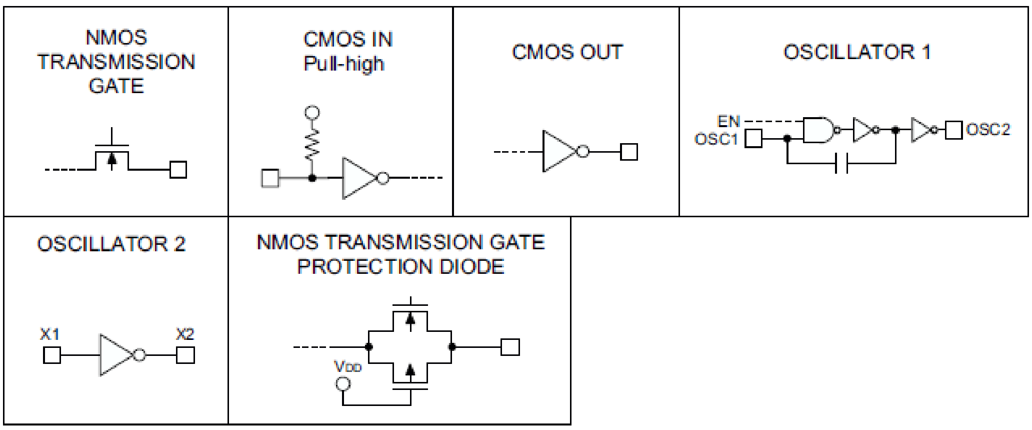
HT12E –20 SOP-A

Pin Description

Pin Name	I/O	Internal Connection	Description
A0~A7	I	CMOS IN Pull-high (HT12A)	Input pins for address A0~A7 setting These pins can be externally set to VSS or left open
		NMOS TRANSMISSION GATE PROTECTION DIODE (HT12E)	
AD8~AD11	I	NMOS TRANSMISSION GATE PROTECTION DIODE (HT12E)	Input pins for address/data AD8~AD11 setting These pins can be externally set to VSS or left open
D8~D11	I	CMOS IN Pull-high	Input pins for data D8~D11 setting and transmission enable, active low These pins should be externally set to VSS or left open (see Note)
DOUT	O	CMOS OUT	Encoder data serial transmission output
L/$\overline{\text{M}}$	I	CMOS IN Pull-high	Latch/Momentary transmission format selection pin: Latch: Floating or VDD Momentary: VSS
$\overline{\text{TE}}$	I	CMOS IN Pull-high	Transmission enable, active low (see Note)
OSC1	I	OSCILLATOR 1	Oscillator input pin
OSC2	O	OSCILLATOR 1	Oscillator output pin
X1	I	OSCILLATOR 2	455kHz resonator oscillator input
X2	O	OSCILLATOR 2	455kHz resonator oscillator output
VSS	I	—	Negative power supply, ground
VDD	I	—	Positive power supply

Note: D8~D11 are all data input and transmission enable pins of the HT12A.
$\overline{\text{TE}}$ is a transmission enable pin of the HT12E.

Approximate Internal Connections



Absolute Maximum Ratings

Supply Voltage (HT12A) ....V_{SS}–0.3V to V_{SS}+5.5V

Input Voltage ....V_{SS}–0.3 to V_{DD}+0.3V

Operating Temperature..........................–20°C to 75°C

Supply Voltage (HT12E) ....–0.3V to 13V

Storage Temperature ....–50°C to 125°C

Note: These are stress ratings only. Stresses exceeding the range specified under "Absolute Maximum Ratings" may cause substantial damage to the device. Functional operation of this device at other conditions beyond those listed in the specification is not implied and prolonged exposure to extreme conditions may affect device reliability.

Electrical Characteristics

HT12A Ta=25°C

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
V_{DD}	Operating Voltage	—	—	2.4	3	5	V
I_{STB}	Standby Current	3V	Oscillator stops	—	0.1	1	μA
		5V		—	0.1	1	μA
I_{DD}	Operating Current	3V	No load f_{OSC}=455kHz	—	200	400	μA
		5V		—	400	800	μA
I_{DOUT}	Output Drive Current	5V	V_{OH}=0.9V_{DD} (Source)	–1	–1.6	—	mA
			V_{OL}=0.1V_{DD} (Sink)	2	3.2	—	mA
V_{IH}	"H" Input Voltage	—	—	0.8V_{DD}	—	V_{DD}	V
V_{IL}	"L" Input Voltage	—	—	0	—	0.2V_{DD}	V
R_{DATA}	D8~D11 Pull-high Resistance	5V	V_{DATA}=0V	—	150	300	kΩ

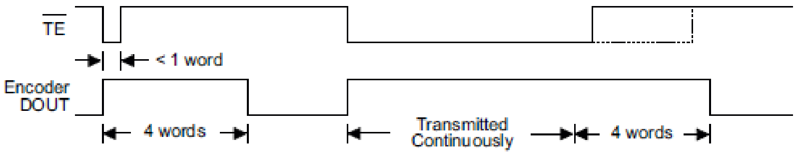
HT12E Ta=25°C

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
V_{DD}	Operating Voltage	—	—	2.4	5	12	V
I_{STB}	Standby Current	3V	Oscillator stops	—	0.1	1	μA
		12V		—	2	4	μA
I_{DD}	Operating Current	3V	No load, f_{OSC}=3kHz	—	40	80	μA
		12V		—	150	300	μA
I_{DOUT}	Output Drive Current	5V	V_{OH}=0.9V_{DD} (Source)	–1	–1.6	—	mA
			V_{OL}=0.1V_{DD} (Sink)	1	1.6	—	mA
V_{IH}	"H" Input Voltage	—	—	0.8V_{DD}	—	V_{DD}	V
V_{IL}	"L" Input Voltage	—	—	0	—	0.2V_{DD}	V
f_{OSC}	Oscillator Frequency	5V	R_{OSC}=1.1MΩ	—	3	—	kHz
$R_{\overline{TE}}$	$\overline{TE}$ Pull-high Resistance	5V	$V_{\overline{TE}}$=0V	—	1.5	3	MΩ

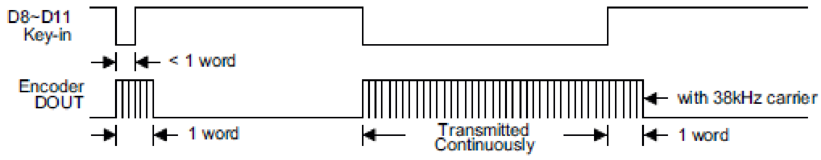
Functional Description

Operation

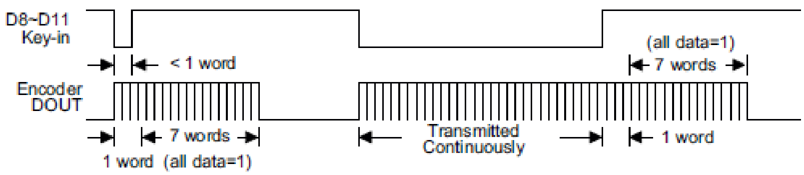
The 2^{12} series of encoders begin a 4-word transmission cycle upon receipt of a transmission enable ($\overline{TE}$ for the HT12E or D8~D11 for the HT12A, active low). This cycle will repeat itself as long as the transmission enable ($\overline{TE}$ or D8~D11) is held low. Once the transmission enable returns high the encoder output completes its final cycle and then stops as shown below.



Transmission timing for the HT12E



Transmission timing for the HT12A (L/$\overline{M}$=Floating or VDD)

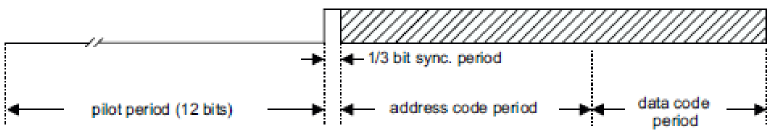


Transmission timing for the HT12A (L/$\overline{M}$=VSS)

Information Word

If L/$\overline{M}$=1 the device is in the latch mode (for use with the latch type of data decoders). When the transmission enable is removed during a transmission, the DOUT pin outputs a complete word and then stops. On the other hand, if L/$\overline{M}$=0 the device is in the momentary mode (for use with the momentary type of data decoders). When the transmission enable is removed during a transmission, the DOUT outputs a complete word and then adds 7 words all with the "1" data code.

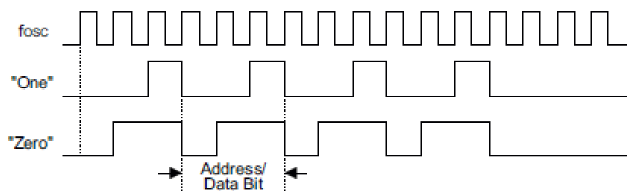
An information word consists of 4 periods as illustrated below.



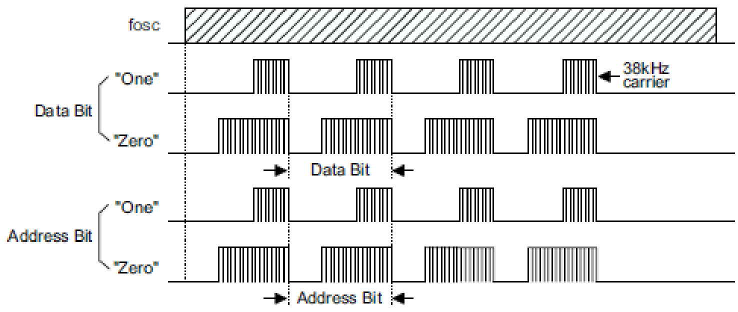
Composition of information

Address/Data Waveform

Each programmable address/data pin can be externally set to one of the following two logic states as shown below.



Address/Data bit waveform for the HT12E



Address/Data bit waveform for the HT12A

The address/data bits of the HT12A are transmitted with a 38kHz carrier for infrared remote controller flexibility.

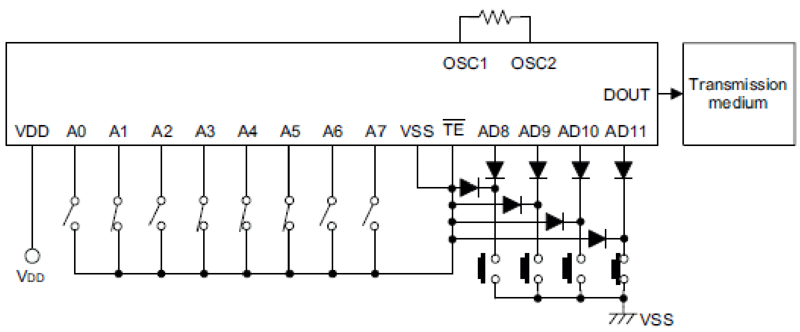
Address/Data Programming (Preset)

The status of each address/data pin can be individually pre-set to logic "high" or "low". If a transmission-enable signal is applied, the encoder scans and transmits the status of the 12 bits of address/data serially in the order A0 to AD11 for the HT12E encoder and A0 to D11 for the HT12A encoder.

During information transmission these bits are transmitted with a preceding synchronization bit. If the trigger signal is not applied, the chip enters the standby mode and consumes a reduced current of less than 1μA for a supply voltage of 5V.

Usual applications preset the address pins with individual security codes using DIP switches or PCB wiring, while the data is selected by push buttons or electronic switches.

The following figure shows an application using the HT12E:



The transmitted information is as shown:

Pilot & Sync.	A0	A1	A2	A3	A4	A5	A6	A7	AD8	AD9	AD10	AD11
	1	0	1	0	0	0	1	1	1	1	1	0

Address/Data Sequence

The following provides the address/data sequence table for various models of the 2^{12} series of encoders.

Part No.	Address/Data Bits											
	0	1	2	3	4	5	6	7	8	9	10	11
HT12A	A0	A1	A2	A3	A4	A5	A6	A7	D8	D9	D10	D11
HT12E	A0	A1	A2	A3	A4	A5	A6	A7	AD8	AD9	AD10	AD11

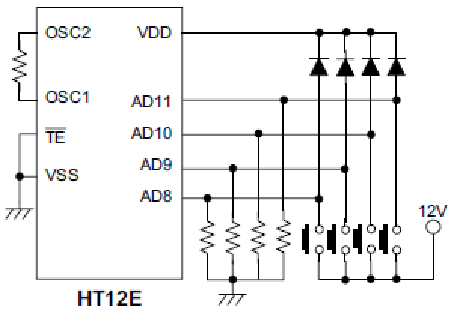
Transmission Enable

For the HT12E encoders, transmission is enabled by applying a low signal to the $\overline{TE}$ pin. For the HT12A encoders, transmission is enabled by applying a low signal to one of the data pins D8~D11.

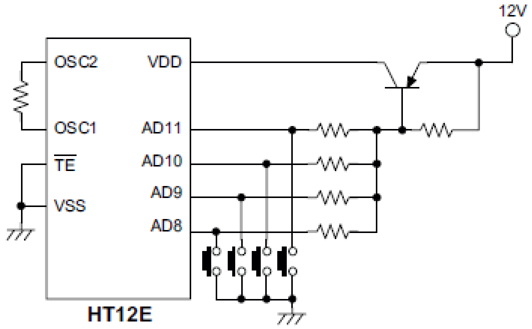
Two Erroneous HT12E Application Circuits

The HT12E must follow closely the application circuits provided by Holtek (see the "Application circuits").

- Error: AD8~AD11 pins input voltage > V_{DD}+0.3V

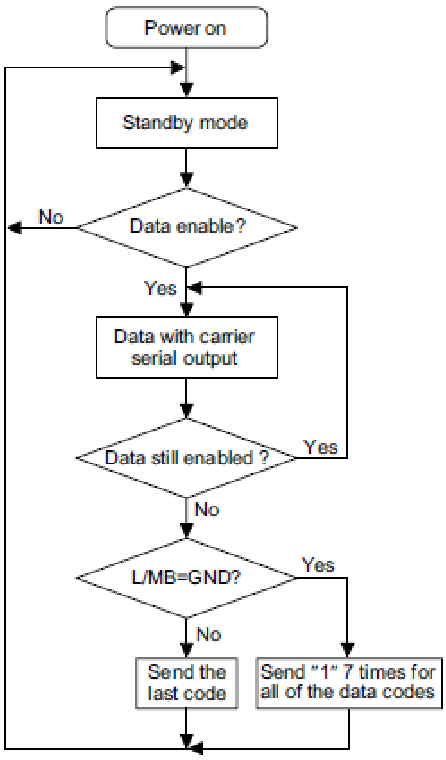


- Error: The IC's power source is activated by pins AD8~AD11

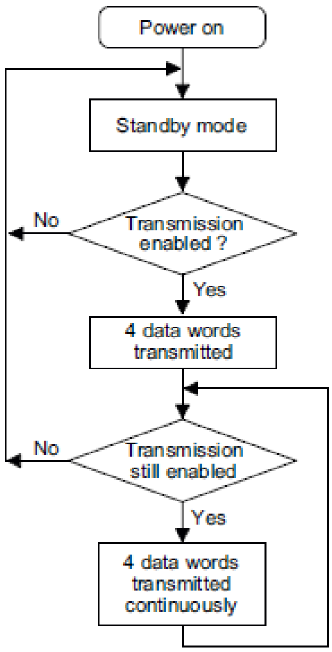


Flowchart

• HT12A

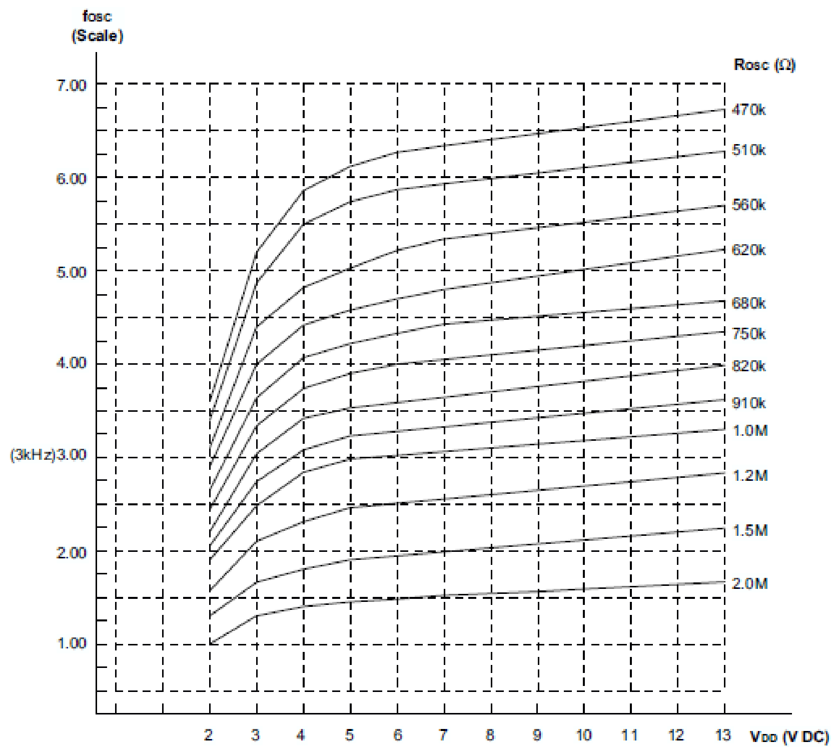


• HT12E



Note: D8~D11 are transmission enables of the HT12A.
$\overline{TE}$ is the transmission enable of the HT12E.

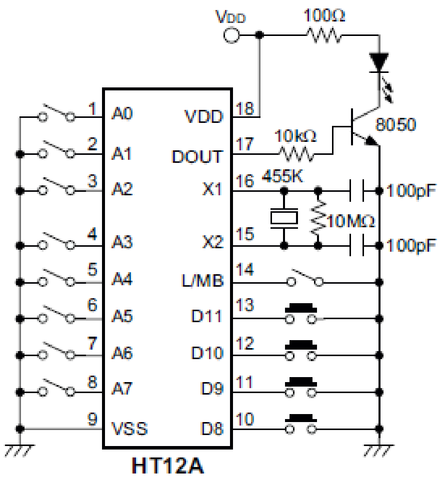
Oscillator Frequency vs. Supply Voltage

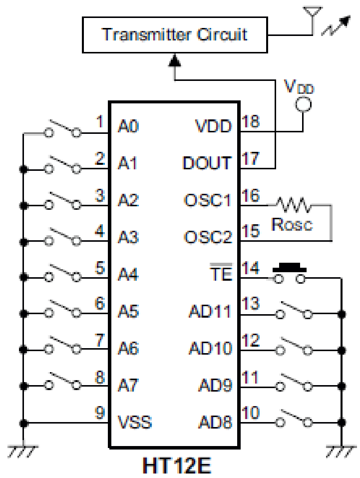


The recommended oscillator frequency is f_{OSCD} (decoder) $\cong 50\ f_{OSCE}$ (HT12E encoder)

$\cong \frac{1}{3} f_{OSCE}$ (HT12A encoder)

Application Circuits





Appendix IV
RF decoder HT12D datasheet

HOLTEK

HT12D/HT12F
2^{12} Series of Decoders

Features

- Operating voltage: 2.4V~12V
- Low power and high noise immunity CMOS technology
- Low standby current
- Capable of decoding 12 bits of information
- Binary address setting
- Received codes are checked 3 times
- Address/Data number combination
  - HT12D: 8 address bits and 4 data bits
  - HT12F: 12 address bits only
- Built-in oscillator needs only 5% resistor
- Valid transmission indicator
- Easy interface with an RF or an infrared transmission medium
- Minimal external components
- Pair with Holtek's 2^{12} series of encoders
- 18-pin DIP, 20-pin SOP package

Applications

- Burglar alarm system
- Smoke and fire alarm system
- Garage door controllers
- Car door controllers
- Car alarm system
- Security system
- Cordless telephones
- Other remote control systems

General Description

The 2^{12} decoders are a series of CMOS LSIs for remote control system applications. They are paired with Holtek's 2^{12} series of encoders (refer to the encoder/decoder cross reference table). For proper operation, a pair of encoder/decoder with the same number of addresses and data format should be chosen.

The decoders receive serial addresses and data from a programmed 2^{12} series of encoders that are transmitted by a carrier using an RF or an IR transmission medium. They compare the serial input data three times continuously with their local addresses. If no error or unmatched codes are found, the input data codes are decoded and then transferred to the output pins. The VT pin also goes high to indicate a valid transmission.

The 2^{12} series of decoders are capable of decoding informations that consist of N bits of address and 12–N bits of data. Of this series, the HT12D is arranged to provide 8 address bits and 4 data bits, and HT12F is used to decode 12 bits of address information.

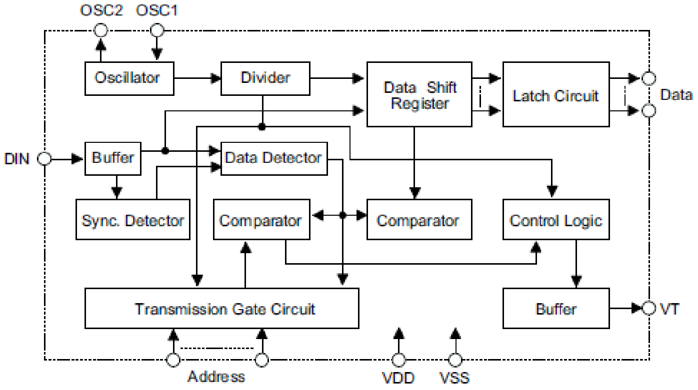
Selection Table

Function / Part No.	Address No.	Data No.	Data Type	VT	Oscillator	Trigger	Package
HT12D	8	4	L	√	RC oscillator	DIN active "Hi"	18DIP, 20SOP
HT12F	12	0	—	√	RC oscillator	DIN active "Hi"	18DIP, 20SOP

Notes: Data type: L stands for latch type data output.

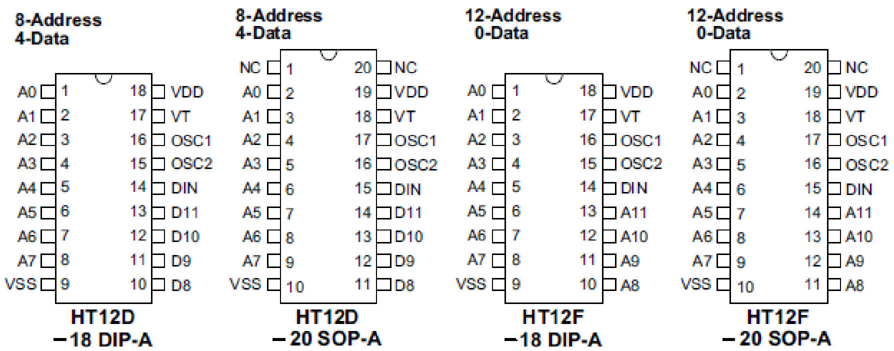
VT can be used as a momentary data output.

Block Diagram



Note: The address/data pins are available in various combinations (see the address/data table).

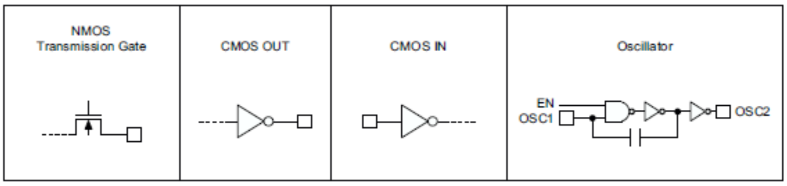
Pin Assignment



Pin Description

Pin Name	I/O	Internal Connection	Description
A0~A11 (HT12F)	I	NMOS Transmission Gate	Input pins for address A0~A11 setting These pins can be externally set to VSS or left open.
A0~A7 (HT12D)			Input pins for address A0~A7 setting These pins can be externally set to VSS or left open.
D8~D11 (HT12D)	O	CMOS OUT	Output data pins, power-on state is low.
DIN	I	CMOS IN	Serial data input pin
VT	O	CMOS OUT	Valid transmission, active high
OSC1	I	Oscillator	Oscillator input pin
OSC2	O	Oscillator	Oscillator output pin
VSS	—	—	Negative power supply, ground
VDD	—	—	Positive power supply

Approximate internal connection circuits



Absolute Maximum Ratings

Supply Voltage ....–0.3V to 13V

Input Voltage ....V_{SS}–0.3 to V_{DD}+0.3V

Storage Temperature ....–50°C to 125°C

Operating Temperature..........................–20°C to 75°C

Note: These are stress ratings only. Stresses exceeding the range specified under "Absolute Maximum Ratings" may cause substantial damage to the device. Functional operation of this device at other conditions beyond those listed in the specification is not implied and prolonged exposure to extreme conditions may affect device reliability.

Electrical Characteristics

Ta=25°C

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
V_{DD}	Operating Voltage	—	—	2.4	5	12	V
I_{STB}	Standby Current	5V	Oscillator stops	—	0.1	1	μA
		12V		—	2	4	μA
I_{DD}	Operating Current	5V	No load, f_{OSC}=150kHz	—	200	400	μA
I_O	Data Output Source Current (D8~D11)	5V	V_{OH}=4.5V	–1	–1.6	—	mA
	Data Output Sink Current (D8~D11)	5V	V_{OL}=0.5V	1	1.6	—	mA
I_{VT}	VT Output Source Current	5V	V_{OH}=4.5V	–1	–1.6	—	mA
	VT Output Sink Current		V_{OL}=0.5V	1	1.6	—	mA
V_{IH}	"H" Input Voltage	5V	—	3.5	—	5	V
V_{IL}	"L" Input Voltage	5V	—	0	—	1	V
f_{OSC}	Oscillator Frequency	5V	R_{OSC}=51kΩ	—	150	—	kHz

Functional Description

Operation

The 2^{12} series of decoders provides various combinations of addresses and data pins in different packages so as to pair with the 2^{12} series of encoders.

The decoders receive data that are transmitted by an encoder and interpret the first N bits of code period as addresses and the last 12–N bits as data, where N is the address code number. A signal on the DIN pin activates the oscillator which in turn decodes the incoming address and data. The decoders will then check the received address three times continuously. If the received address codes all match the contents of the decoder's local address, the 12–N bits of data are decoded to activate the output pins and the VT pin is set high to indicate a valid transmission. This will last unless the address code is incorrect or no signal is received.

The output of the VT pin is high only when the transmission is valid. Otherwise it is always low.

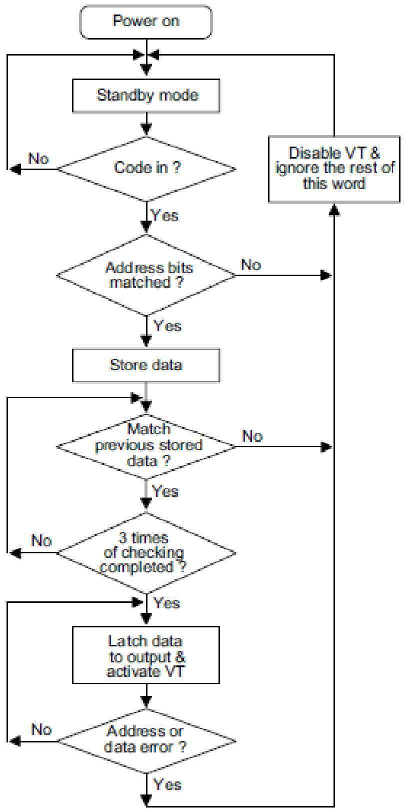
Output type

Of the 2^{12} series of decoders, the HT12F has no data output pin but its VT pin can be used as a momentary data output. The HT12D, on the other hand, provides 4 latch type data pins whose data remain unchanged until new data are received.

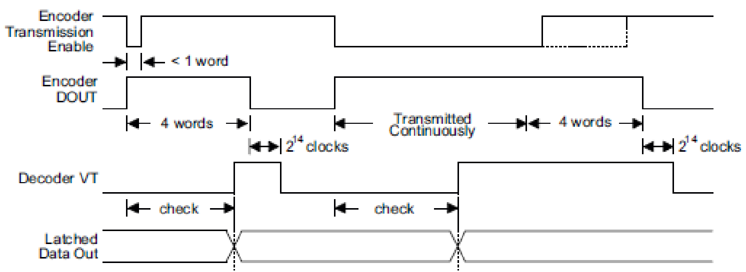
Part No.	Data Pins	Address Pins	Output Type	Operating Voltage
HT12D	4	8	Latch	2.4V~12V
HT12F	0	12	—	2.4V~12V

Flowchart

The oscillator is disabled in the standby state and activated when a logic "high" signal applies to the DIN pin. That is to say, the DIN should be kept low if there is no signal input.



Decoder timing



Encoder/Decoder cross reference table

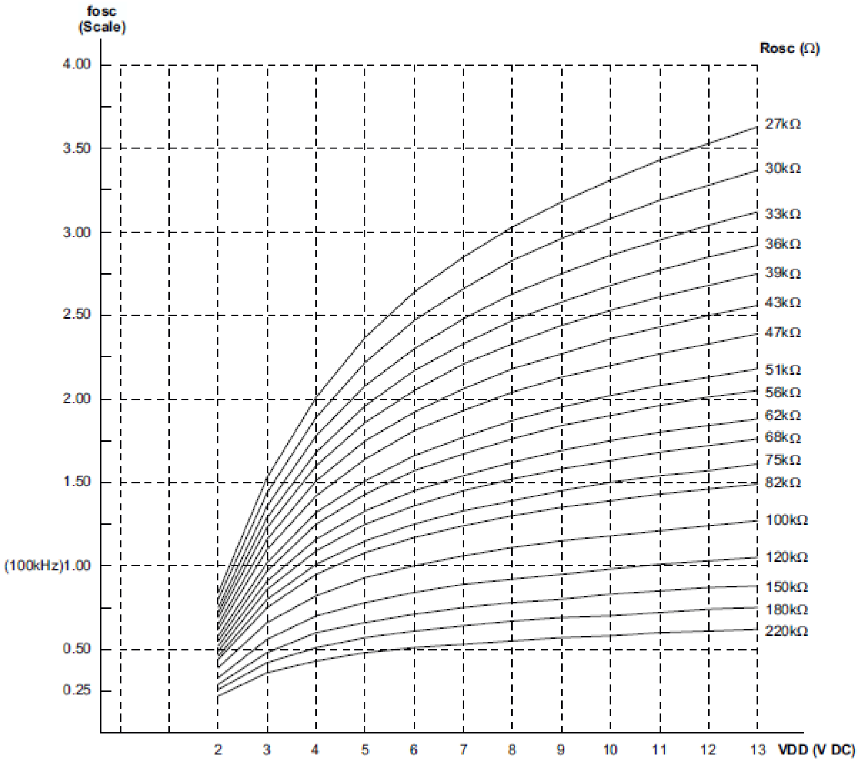
Decoders Part No.	Data Pins	Address Pins	VT	Pair Encoder	Package			
					Encoder		Decoder	
					DIP	SOP	DIP	SOP
HT12D	4	8	√	HT12A HT12E	18	20	18	20
HT12F	0	12	√	HT12A HT12E	18	20	18	20

Address/Data sequence

The following table provides address/data sequence for various models of the 2^{12} series of decoders.

Part No.	Address/Data Bits											
	0	1	2	3	4	5	6	7	8	9	10	11
HT12D	A0	A1	A2	A3	A4	A5	A6	A7	D8	D9	D10	D11
HT12F	A0	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11

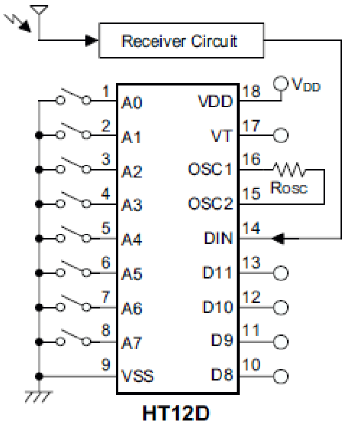
Oscillator frequency vs supply voltage

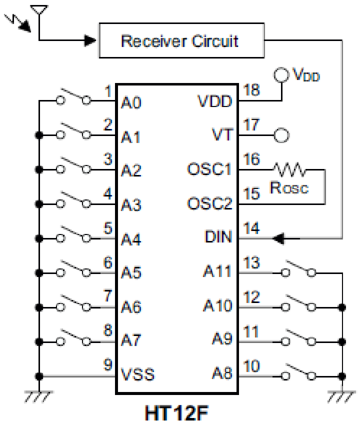


Note: The recommended oscillator frequency is f_{OSCD} (decoder) $\cong 50\ f_{OSCE}$ (HT12E encoder)

$\cong \frac{1}{3} f_{OSCE}$ (HT12A encoder).

Application Circuits





Holtek Semiconductor Inc. (Headquarters)
No.3, Creation Rd. II, Science Park, Hsinchu, Taiwan
Tel: 886-3-563-1999
Fax: 886-3-563-1189
http://www.holtek.com.tw

Holtek Semiconductor Inc. (Taipei Sales Office)
4F-2, No. 3-2, YuanQu St., Nankang Software Park, Taipei 115, Taiwan
Tel: 886-2-2655-7070
Fax: 886-2-2655-7373
Fax: 886-2-2655-7383 (International sales hotline)

Holtek Semiconductor Inc. (Shanghai Sales Office)
7th Floor, Building 2, No.889, Yi Shan Rd., Shanghai, China 200233
Tel: 021-6485-5560
Fax: 021-6485-0313
http://www.holtek.com.cn

Holtek Semiconductor Inc. (Shenzhen Sales Office)
5/F, Unit A, Productivity Building, Cross of Science M 3rd Road and Gaoxin M 2nd Road, Science Park, Nanshan District, Shenzhen, China 518057
Tel: 0755-8616-9908, 8616-9308
Fax: 0755-8616-9533

Holtek Semiconductor Inc. (Beijing Sales Office)
Suite 1721, Jinyu Tower, A129 West Xuan Wu Men Street, Xicheng District, Beijing, China 100031
Tel: 010-6641-0030, 6641-7751, 6641-7752
Fax: 010-6641-0125

Holtek Semiconductor Inc. (Chengdu Sales Office)
709, Building 3, Champagne Plaza, No.97 Dongda Street, Chengdu, Sichuan, China 610016
Tel: 028-6653-6590
Fax: 028-6653-6591

Holmate Semiconductor, Inc. (North America Sales Office)
46729 Fremont Blvd., Fremont, CA 94538
Tel: 510-252-9880
Fax: 510-252-9885
http://www.holmate.com

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Appendix V
DMF(Dual Tone Multi Frequency) datasheet

ISO^2-CMOS **MT8870D/MT8870D-1**

Integrated DTMF Receiver

Features

- Complete DTMF Receiver
- Low power consumption
- Internal gain setting amplifier
- Adjustable guard time
- Central office quality
- Power-down mode
- Inhibit mode
- Backward compatible with MT8870C/MT8870C-1

Applications

- Receiver system for British Telecom (BT) or CEPT Spec (MT8870D-1)
- Paging systems
- Repeater systems/mobile radio
- Credit card systems
- Remote control
- Personal computers
- Telephone answering machine

ISSUE 3 May1995

Ordering Information

MT8870DE/DE-1	18 Pin Plastic DIP
MT8870DC/DC-1	18 Pin Ceramic DIP
MT8870DS/DS-1	18 Pin SOIC
MT8870DN/DN-1	20 Pin SSOP
MT8870DT/DT-1	20 Pin TSSOP

-40 °C to +85 °C

Description

The MT8870D/MT8870D-1 is a complete DTMF receiver integrating both the bandsplit filter and digital decoder functions. The filter section uses switched capacitor techniques for high and low group filters; the decoder uses digital counting techniques to detect and decode all 16 DTMF tone-pairs into a 4-bit code. External component count is minimized by on chip provision of a differential input amplifier, clock oscillator and latched three-state bus interface.

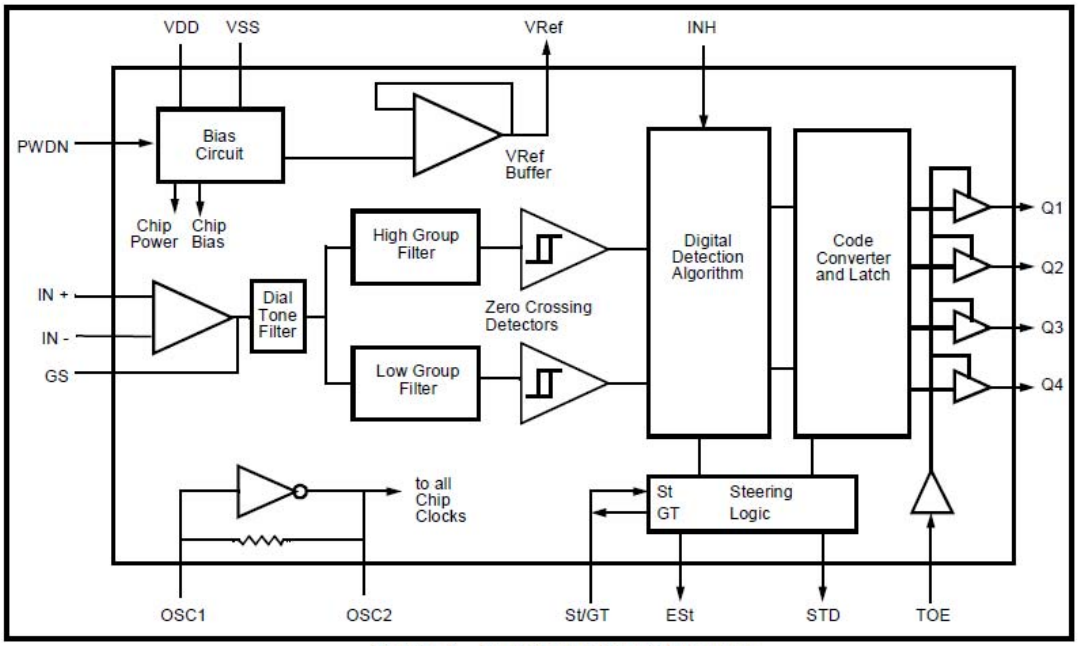


Figure 1 - Functional Block Diagram

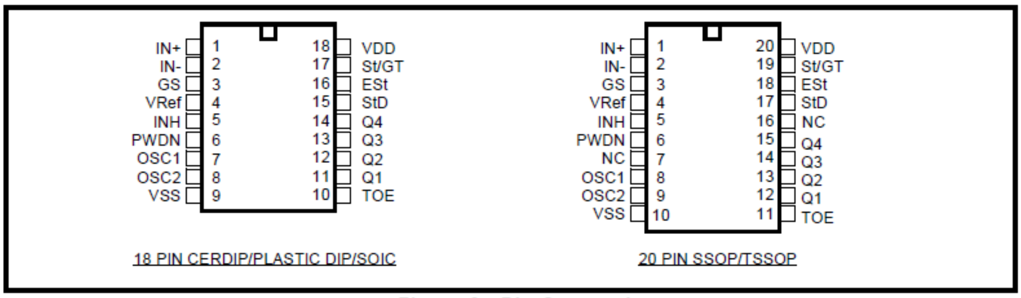


Figure 2 - Pin Connections

Pin Description

Pin #		Name	Description
18	20		
1	1	IN+	**Non-Inverting Op-Amp (Input).**
2	2	IN-	**Inverting Op-Amp (Input).**
3	3	GS	**Gain Select.** Gives access to output of front end differential amplifier for connection of feedback resistor.
4	4	V_{Ref}	**Reference Voltage (Output).** Nominally $V_{DD}/2$ is used to bias inputs at mid-rail (see Fig. 6 and Fig. 10).
5	5	INH	**Inhibit (Input).** Logic high inhibits the detection of tones representing characters A, B, C and D. This pin input is internally pulled down.
6	6	PWDN	**Power Down (Input).** Active high. Powers down the device and inhibits the oscillator. This pin input is internally pulled down.
7	8	OSC1	**Clock (Input).**
8	9	OSC2	**Clock (Output).** A 3.579545 MHz crystal connected between pins OSC1 and OSC2 completes the internal oscillator circuit.
9	10	V_{SS}	**Ground (Input).** 0V typical.
10	11	TOE	**Three State Output Enable (Input).** Logic high enables the outputs Q1-Q4. This pin is pulled up internally.
11-14	12-15	Q1-Q4	**Three State Data (Output).** When enabled by TOE, provide the code corresponding to the last valid tone-pair received (see Table 1). When TOE is logic low, the data outputs are high impedance.
15	17	StD	**Delayed Steering (Output).** Presents a logic high when a received tone-pair has been registered and the output latch updated; returns to logic low when the voltage on St/GT falls below V_{TSt}.
16	18	ESt	**Early Steering (Output).** Presents a logic high once the digital algorithm has detected a valid tone pair (signal condition). Any momentary loss of signal condition will cause ESt to return to a logic low.
17	19	St/GT	**Steering Input/Guard time (Output) Bidirectional.** A voltage greater than V_{TSt} detected at St causes the device to register the detected tone pair and update the output latch. A voltage less than V_{TSt} frees the device to accept a new tone pair. The GT output acts to reset the external steering time-constant; its state is a function of ESt and the voltage on St.
18	20	V_{DD}	**Positive power supply (Input).** +5V typical.
	7, 16	NC	No Connection.

Functional Description

The MT8870D/MT8870D-1 monolithic DTMF receiver offers small size, low power consumption and high performance. Its architecture consists of a bandsplit filter section, which separates the high and low group tones, followed by a digital counting section which verifies the frequency and duration of the received tones before passing the corresponding code to the output bus.

Filter Section

Separation of the low-group and high group tones is achieved by applying the DTMF signal to the inputs of two sixth-order switched capacitor bandpass filters, the bandwidths of which correspond to the low and high group frequencies. The filter section also incorporates notches at 350 and 440 Hz for exceptional dial tone rejection (see Figure 3). Each filter output is followed by a single order switched capacitor filter section which smooths the signals prior to limiting. Limiting is performed by high-gain comparators which are provided with hysteresis to prevent detection of unwanted low-level signals. The outputs of the comparators provide full rail logic swings at the frequencies of the incoming DTMF signals.

Decoder Section

Following the filter section is a decoder employing digital counting techniques to determine the frequencies of the incoming tones and to verify that they correspond to standard DTMF frequencies. A complex averaging algorithm protects against tone simulation by extraneous signals such as voice while

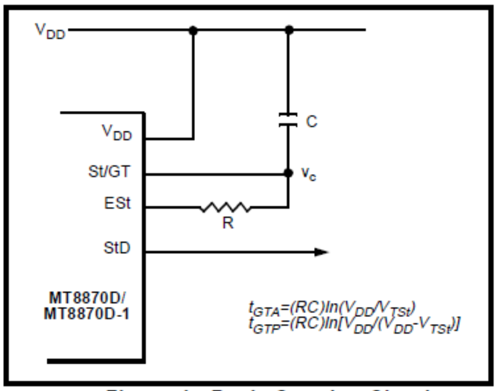


Figure 4 - Basic Steering Circuit

providing tolerance to small frequency deviations and variations. This averaging algorithm has been developed to ensure an optimum combination of immunity to talk-off and tolerance to the presence of interfering frequencies (third tones) and noise. When the detector recognizes the presence of two valid tones (this is referred to as the "signal condition" in some industry specifications) the "Early Steering" (ESt) output will go to an active state. Any subsequent loss of signal condition will cause ESt to assume an inactive state (see "Steering Circuit").

Steering Circuit

Before registration of a decoded tone pair, the receiver checks for a valid signal duration (referred to as character recognition condition). This check is performed by an external RC time constant driven by ESt. A logic high on ESt causes v_c (see Figure 4) to rise as the capacitor discharges. Provided signal

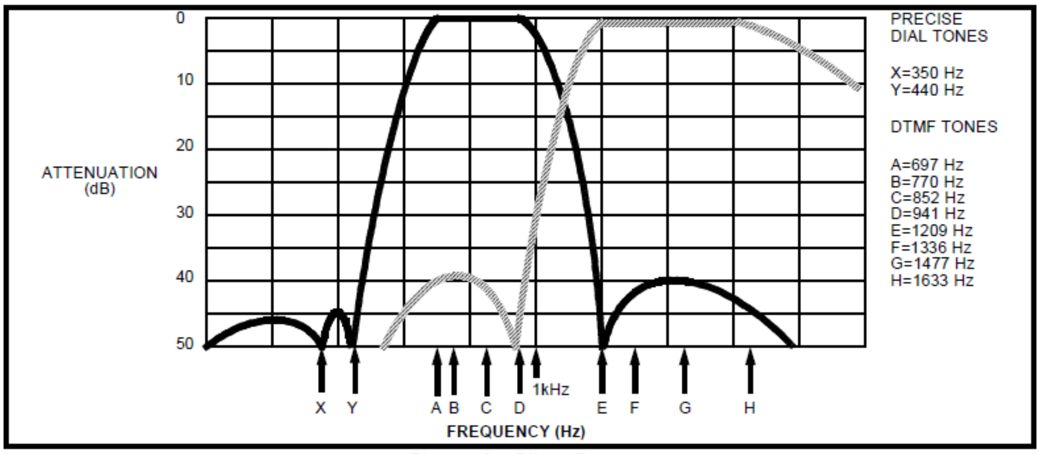


Figure 3 - Filter Response

condition is maintained (ESt remains high) for the validation period (t_{GTP}), v_c reaches the threshold (V_{TSt}) of the steering logic to register the tone pair, latching its corresponding 4-bit code (see Table 1) into the output latch. At this point the GT output is activated and drives v_c to V_{DD}. GT continues to drive high as long as ESt remains high. Finally, after a short delay to allow the output latch to settle, the delayed steering output flag (StD) goes high, signalling that a received tone pair has been registered. The contents of the output latch are made available on the 4-bit output bus by raising the three state control input (TOE) to a logic high. The steering circuit works in reverse to validate the interdigit pause between signals. Thus, as well as rejecting signals too short to be considered valid, the receiver will tolerate signal interruptions (dropout) too short to be considered a valid pause. This facility, together with the capability of selecting the steering time constants externally, allows the designer to tailor performance to meet a wide variety of system requirements.

Guard Time Adjustment

In many situations not requiring selection of tone duration and interdigital pause, the simple steering circuit shown in Figure 4 is applicable. Component values are chosen according to the formula:

$$t_{REC}=t_{DP}+t_{GTP}$$
$$t_{ID}=t_{DA}+t_{GTA}$$

The value of t_{DP} is a device parameter (see Figure 11) and t_{REC} is the minimum signal duration to be recognized by the receiver. A value for C of 0.1 µF is recommended for most applications, leaving R to be selected by the designer.

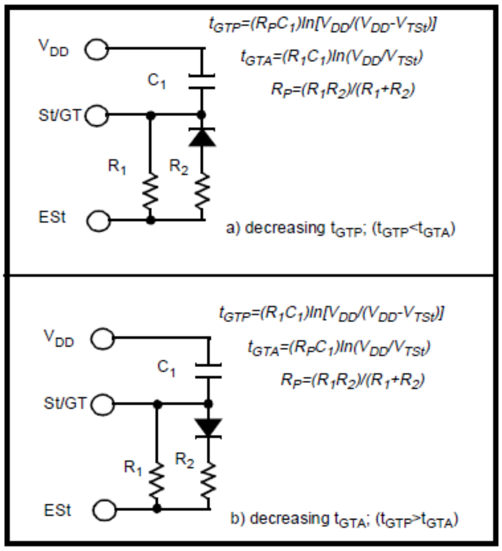


Figure 5 - Guard Time Adjustment

Digit	TOE	INH	ESt	Q_4	Q_3	Q_2	Q_1
ANY	L	X	H	Z	Z	Z	Z
1	H	X	H	0	0	0	1
2	H	X	H	0	0	1	0
3	H	X	H	0	0	1	1
4	H	X	H	0	1	0	0
5	H	X	H	0	1	0	1
6	H	X	H	0	1	1	0
7	H	X	H	0	1	1	1
8	H	X	H	1	0	0	0
9	H	X	H	1	0	0	1
0	H	X	H	1	0	1	0
*	H	X	H	1	0	1	1
#	H	X	H	1	1	0	0
A	H	L	H	1	1	0	1
B	H	L	H	1	1	1	0
C	H	L	H	1	1	1	1
D	H	L	H	0	0	0	0
A	H	H	L	undetected, the output code will remain the same as the previous detected code			
B	H	H	L				
C	H	H	L				
D	H	H	L				

Table 1. Functional Decode Table

L=LOGIC LOW, H=LOGIC HIGH, Z=HIGH IMPEDANCE
X = DON'T CARE

Different steering arrangements may be used to select independently the guard times for tone present (t_{GTP}) and tone absent (t_{GTA}). This may be necessary to meet system specifications which place both accept and reject limits on both tone duration and interdigital pause. Guard time adjustment also allows the designer to tailor system parameters such as talk off and noise immunity. Increasing t_{REC} improves talk-off performance since it reduces the probability that tones simulated by speech will maintain signal condition long enough to be registered. Alternatively, a relatively short t_{REC} with a long t_{DO} would be appropriate for extremely noisy environments where fast acquisition time and immunity to tone drop-outs are required. Design information for guard time adjustment is shown in Figure 5.

Power-down and Inhibit Mode

A logic high applied to pin 6 (PWDN) will power down the device to minimize the power consumption in a standby mode. It stops the oscillator and the functions of the filters.

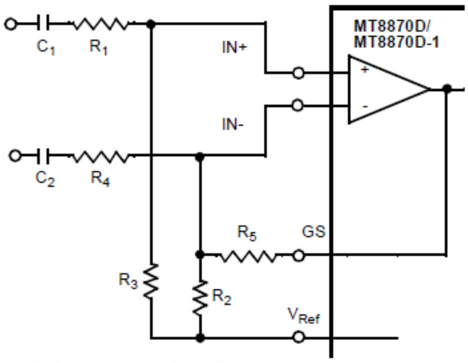
Inhibit mode is enabled by a logic high input to the pin 5 (INH). It inhibits the detection of tones representing characters A, B, C, and D. The output code will remain the same as the previous detected code (see Table 1).

Differential Input Configuration

The input arrangement of the MT8870D/MT8870D-1 provides a differential-input operational amplifier as well as a bias source (V_{Ref}) which is used to bias the inputs at mid-rail. Provision is made for connection of a feedback resistor to the op-amp output (GS) for adjustment of gain. In a single-ended configuration, the input pins are connected as shown in Figure 10 with the op-amp connected for unity gain and V_{Ref} biasing the input at $^1/_2V_{DD}$. Figure 6 shows the differential configuration, which permits the adjustment of gain with the feedback resistor R_5.

Crystal Oscillator

The internal clock circuit is completed with the addition of an external 3.579545 MHz crystal and is normally connected as shown in Figure 10 (Single-Ended Input Configuration). However, it is possible to configure several MT8870D/MT8870D-1 devices employing only a single oscillator crystal. The oscillator output of the first device in the chain is coupled through a 30 pF capacitor to the oscillator input (OSC1) of the next device. Subsequent devices are connected in a similar fashion. Refer to Figure 7 for details. The problems associated with unbalanced loading are not a concern with the arrangement shown, i.e., precision balancing capacitors are not required.



Differential Input Amplifier
$C_1=C_2=10$ nF
$R_1=R_4=R_5=100$ kΩ
$R_2=60$kΩ, $R_3=37.5$ kΩ

All resistors are ±1% tolerance.
All capacitors are ±5% tolerance.

$$R_3=\frac{R_2R_5}{R_2+R_5}$$

$$\text{VOLTAGE GAIN } (A_v \text{ diff})=\frac{R_5}{R_1}$$

INPUT IMPEDANCE

$$(Z_{INDIFF})=2\sqrt{R_1^2+\left(\frac{1}{\omega c}\right)^2}$$

Figure 6 - Differential Input Configuration

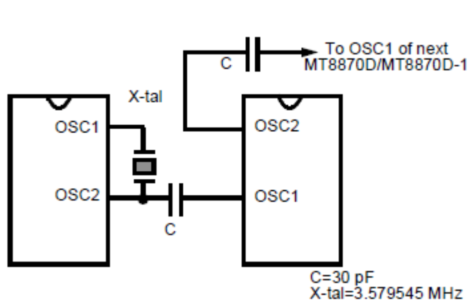


Figure 7 - Oscillator Connection

Parameter	Unit	Resonator
R1	Ohms	10.752
L1	mH	.432
C1	pF	4.984
C0	pF	37.915
Qm	-	896.37
Δf	%	±0.2%

Table 2. Recommended Resonator Specifications
Note: Qm=quality factor of RLC model, i.e., 1/2Π*f*R1C1.

Appendix VI
MAX32 data sheet

19-4323; Rev 9; 4/00

MAXIM

+5V-Powered, Multichannel RS-232 Drivers/Receivers

General Description

The MAX220–MAX249 family of line drivers/receivers is intended for all EIA/TIA-232E and V.28/V.24 communications interfaces, particularly applications where ±12V is not available.

These parts are especially useful in battery-powered systems, since their low-power shutdown mode reduces power dissipation to less than 5μW. The MAX225, MAX233, MAX235, and MAX245/MAX246/MAX247 use no external components and are recommended for applications where printed circuit board space is critical.

Applications

Portable Computers

Low-Power Modems

Interface Translation

Battery-Powered RS-232 Systems

Multidrop RS-232 Networks

Features

Superior to Bipolar

- ♦ Operate from Single +5V Power Supply (+5V and +12V—MAX231/MAX239)
- ♦ Low-Power Receive Mode in Shutdown (MAX223/MAX242)
- ♦ Meet All EIA/TIA-232E and V.28 Specifications
- ♦ Multiple Drivers and Receivers
- ♦ 3-State Driver and Receiver Outputs
- ♦ Open-Line Detection (MAX243)

Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX220CPE	0°C to +70°C	16 Plastic DIP
MAX220CSE	0°C to +70°C	16 Narrow SO
MAX220CWE	0°C to +70°C	16 Wide SO
MAX220C/D	0°C to +70°C	Dice*
MAX220EPE	-40°C to +85°C	16 Plastic DIP
MAX220ESE	-40°C to +85°C	16 Narrow SO
MAX220EWE	-40°C to +85°C	16 Wide SO
MAX220EJE	-40°C to +85°C	16 CERDIP
MAX220MJE	-55°C to +125°C	16 CERDIP

Ordering Information continued at end of data sheet.

*Contact factory for dice specifications.

Selection Table

Part Number	Power Supply (V)	No. of RS-232 Drivers/Rx	No. of Ext. Caps	Nominal Cap. Value (μF)	SHDN & Three-State	Rx Active in SHDN	Data Rate (kbps)	Features
MAX220	+5	2/2	4	4.7/10	No	—	120	Ultra-low-power, industry-standard pinout
MAX222	+5	2/2	4	0.1	Yes	—	200	Low-power shutdown
MAX223 (MAX213)	+5	4/5	4	1.0 (0.1)	Yes	✔	120	MAX241 and receivers active in shutdown
MAX225	+5	5/5	0	—	Yes	✔	120	Available in SO
MAX230 (MAX200)	+5	5/0	4	1.0 (0.1)	Yes	—	120	5 drivers with shutdown
MAX231 (MAX201)	+5 and +7.5 to +13.2	2/2	2	1.0 (0.1)	No	—	120	Standard +5/+12V or battery supplies; same functions as MAX232
MAX232 (MAX202)	+5	2/2	4	1.0 (0.1)	No	—	120 (64)	Industry standard
MAX232A	+5	2/2	4	0.1	No	—	200	Higher slew rate, small caps
MAX233 (MAX203)	+5	2/2	0	—	No	—	120	No external caps
MAX233A	+5	2/2	0	—	No	—	200	No external caps, high slew rate
MAX234 (MAX204)	+5	4/0	4	1.0 (0.1)	No	—	120	Replaces 1488
MAX235 (MAX205)	+5	5/5	0	—	Yes	—	120	No external caps
MAX236 (MAX206)	+5	4/3	4	1.0 (0.1)	Yes	—	120	Shutdown, three state
MAX237 (MAX207)	+5	5/3	4	1.0 (0.1)	No	—	120	Complements IBM PC serial port
MAX238 (MAX208)	+5	4/4	4	1.0 (0.1)	No	—	120	Replaces 1488 and 1489
MAX239 (MAX209)	+5 and +7.5 to +13.2	3/5	2	1.0 (0.1)	No	—	120	Standard +5/+12V or battery supplies; single-package solution for IBM PC serial port
MAX240	+5	5/5	4	1.0	Yes	—	120	DIP or flatpack package
MAX241 (MAX211)	+5	4/5	4	1.0 (0.1)	Yes	—	120	Complete IBM PC serial port
MAX242	+5	2/2	4	0.1	Yes	✔	200	Separate shutdown and enable
MAX243	+5	2/2	4	0.1	No	—	200	Open-line detection simplifies cabling
MAX244	+5	8/10	4	1.0	No	—	120	High slew rate
MAX245	+5	8/10	0	—	Yes	✔	120	High slew rate, int. caps, two shutdown modes
MAX246	+5	8/10	0	—	Yes	✔	120	High slew rate, int. caps, three shutdown modes
MAX247	+5	8/9	0	—	Yes	✔	120	High slew rate, int. caps, nine operating modes
MAX248	+5	8/8	4	1.0	Yes	✔	120	High slew rate, selective half-chip enables
MAX249	+5	6/10	4	1.0	Yes	✔	120	Available in quad flatpack package

+5V-Powered, Multichannel RS-232 Drivers/Receivers

ABSOLUTE MAXIMUM RATINGS—MAX220/222/232A/233A/242/243

Supply Voltage (V_{CC}) ....-0.3V to +6V
Input Voltages
T_{IN}....................-0.3V to (V_{CC} - 0.3V)
R_{IN} (Except MAX220) ....±30V
R_{IN} (MAX220)....................±25V
T_{OUT} (Except MAX220) (Note 1) ....±15V
T_{OUT} (MAX220)....................±13.2V
Output Voltages
T_{OUT}....................±15V
R_{OUT}....................-0.3V to (V_{CC} + 0.3V)
Driver/Receiver Output Short Circuited to GND.........Continuous
Continuous Power Dissipation (T_A = +70°C)
16-Pin Plastic DIP (derate 10.53mW/°C above +70°C)....842mW
18-Pin Plastic DIP (derate 11.11mW/°C above +70°C)....889mW
20-Pin Plastic DIP (derate 8.00mW/°C above +70°C) ..440mW
16-Pin Narrow SO (derate 8.70mW/°C above +70°C) ...696mW
16-Pin Wide SO (derate 9.52mW/°C above +70°C)......762mW
18-Pin Wide SO (derate 9.52mW/°C above +70°C)......762mW
20-Pin Wide SO (derate 10.00mW/°C above +70°C)....800mW
20-Pin SSOP (derate 8.00mW/°C above +70°C) 640mW
16-Pin CERDIP (derate 10.00mW/°C above +70°C).....800mW
18-Pin CERDIP (derate 10.53mW/°C above +70°C).....842mW
Operating Temperature Ranges
MAX2_ _AC_ _, MAX2_ _C_ _....................0°C to +70°C
MAX2_ _AE_ _, MAX2_ _E_ _....................-40°C to +85°C
MAX2_ _AM_ _, MAX2_ _M_ _....................-55°C to +125°C
Storage Temperature Range....................-65°C to +160°C
Lead Temperature (soldering, 10sec)....................+300°C

Note 1: Input voltage measured with T_{OUT} in high-impedance state, $\overline{SHDN}$ or V_{CC} = 0V.
Note 2: For the MAX220, V+ and V- can have a maximum magnitude of 7V, but their absolute difference cannot exceed 13V.

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS—MAX220/222/232A/233A/242/243

(V_{CC} = +5V ±10%, C1–C4 = 0.1µF, MAX220, C1 = 0.047µF, C2–C4 = 0.33µF, T_A = T_{MIN} to T_{MAX}, unless otherwise noted.)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
RS-232 TRANSMITTERS						
Output Voltage Swing	All transmitter outputs loaded with 3kΩ to GND		±5	±8		V
Input Logic Threshold Low				1.4	0.8	V
Input Logic Threshold High	All except MAX220		2	1.4		V
	MAX220: V_{CC} = 5.0V		2.4			
Logic Pull-Up/Input Current	All except MAX220, normal operation			5	40	µA
	$\overline{SHDN}$ = 0V, MAX222/242, shutdown, MAX220			±0.01	±1	
Output Leakage Current	V_{CC} = 5.5V, $\overline{SHDN}$ = 0V, V_{OUT} = ±15V, MAX222/242			±0.01	±10	µA
	V_{CC} = $\overline{SHDN}$ = 0V, V_{OUT} = ±15V			±0.01	±10	
Data Rate	All except MAX220, normal operation			200	116	kb/s
Transmitter Output Resistance	V_{CC} = V+ = V- = 0V, V_{OUT} = ±2V		300	10M		Ω
Output Short-Circuit Current	V_{OUT} = 0V		±7	±22		mA
RS-232 RECEIVERS						
RS-232 Input Voltage Operating Range					±30	V
RS-232 Input Threshold Low	V_{CC} = 5V	All except MAX243 $R2_{IN}$	0.8	1.3		V
		MAX243 $R2_{IN}$ (Note 2)	-3			
RS-232 Input Threshold High	V_{CC} = 5V	All except MAX243 $R2_{IN}$		1.8	2.4	V
		MAX243 $R2_{IN}$ (Note 2)		-0.5	-0.1	
RS-232 Input Hysteresis	All except MAX243, V_{CC} = 5V, no hysteresis in shdn.		0.2	0.5	1	V
	MAX243			1		
RS-232 Input Resistance			3	5	7	kΩ
TTL/CMOS Output Voltage Low	I_{OUT} = 3.2mA			0.2	0.4	V
TTL/CMOS Output Voltage High	I_{OUT} = -1.0mA		3.5	V_{CC} - 0.2		V
TTL/CMOS Output Short-Circuit Current	Sourcing V_{OUT} = GND		-2	-10		mA
	Shrinking V_{OUT} = V_{CC}		10	30		

ELECTRICAL CHARACTERISTICS—MAX220/222/232A/233A/242/243 (continued)

(V_{CC} = +5V ±10%, C1–C4 = 0.1µF, MAX220, C1 = 0.047µF, C2–C4 = 0.33µF, T_A = T_{MIN} to T_{MAX}, unless otherwise noted.)

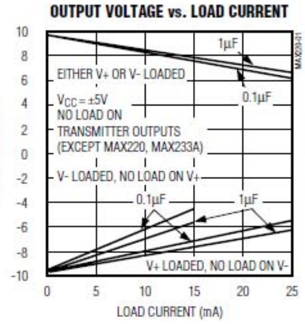
PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
TTL/CMOS Output Leakage Current	$\overline{SHDN}$ = V_{CC} or $\overline{EN}$ = V_{CC} ($\overline{SHDN}$ = 0V for MAX222), 0V ≤ V_{OUT} ≤ V_{CC}			±0.05	±10	µA
$\overline{EN}$ Input Threshold Low	MAX242			1.4	0.8	V
$\overline{EN}$ Input Threshold High	MAX242		2.0	1.4		V
Operating Supply Voltage			4.5		5.5	V
V_{CC} Supply Current ($\overline{SHDN}$ = V_{CC}), Figures 5, 6, 11, 19	No load	MAX220		0.5	2	mA
		MAX222/232A/233A/242/243		4	10	
	3kΩ load both inputs	MAX220		12		
		MAX222/232A/233A/242/243		15		
Shutdown Supply Current	MAX222/242	T_A = +25°C		0.1	10	µA
		T_A = 0°C to +70°C		2	50	
		T_A = -40°C to +85°C		2	50	
		T_A = -55°C to +125°C		35	100	
$\overline{SHDN}$ Input Leakage Current	MAX222/242				±1	µA
$\overline{SHDN}$ Threshold Low	MAX222/242			1.4	0.8	V
$\overline{SHDN}$ Threshold High	MAX222/242		2.0	1.4		V
Transition Slew Rate	C_L = 50pF to 2500pF, R_L = 3kΩ to 7kΩ, V_{CC} = 5V, T_A = +25°C, measured from +3V to -3V or -3V to +3V	MAX222/232A/233A/242/243	6	12	30	V/µs
		MAX220	1.5	3	30	
Transmitter Propagation Delay TLL to RS-232 (normal operation), Figure 1	t_{PHLT}	MAX222/232A/233A/242/243		1.3	3.5	µs
		MAX220		4	10	
	t_{PLHT}	MAX222/232A/233A/242/243		1.5	3.5	
		MAX220		5	10	
Receiver Propagation Delay RS-232 to TLL (normal operation), Figure 2	t_{PHLR}	MAX222/232A/233A/242/243		0.5	1	µs
		MAX220		0.6	3	
	t_{PLHR}	MAX222/232A/233A/242/243		0.6	1	
		MAX220		0.8	3	
Receiver Propagation Delay RS-232 to TLL (shutdown), Figure 2	t_{PHLS}	MAX242		0.5	10	µs
	t_{PLHS}	MAX242		2.5	10	
Receiver-Output Enable Time, Figure 3	t_{ER}	MAX242		125	500	ns
Receiver-Output Disable Time, Figure 3	t_{DR}	MAX242		160	500	ns
Transmitter-Output Enable Time ($\overline{SHDN}$ goes high), Figure 4	t_{ET}	MAX222/242, 0.1µF caps (includes charge-pump start-up)		250		µs
Transmitter-Output Disable Time ($\overline{SHDN}$ goes low), Figure 4	t_{DT}	MAX222/242, 0.1µF caps		600		ns
Transmitter + to - Propagation Delay Difference (normal operation)	t_{PHLT} - t_{PLHT}	MAX222/232A/233A/242/243		300		ns
		MAX220		2000		
Receiver + to - Propagation Delay Difference (normal operation)	t_{PHLR} - t_{PLHR}	MAX222/232A/233A/242/243		100		ns
		MAX220		225		

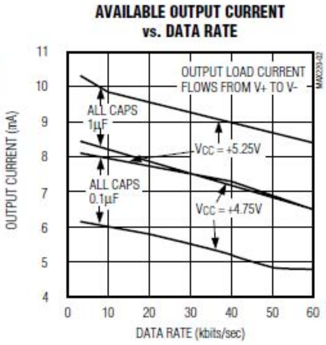
Note 3: MAX243 $R2_{OUT}$ is guaranteed to be low when $R2_{IN}$ is ≥ 0V or is floating.

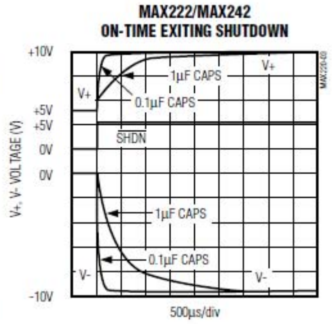
+5V-Powered, Multichannel RS-232 Drivers/Receivers

Typical Operating Characteristics

MAX220/MAX222/MAX232A/MAX233A/MAX242/MAX243







ELECTRICAL CHARACTERISTICS—MAX223/MAX230–MAX241 (continued)

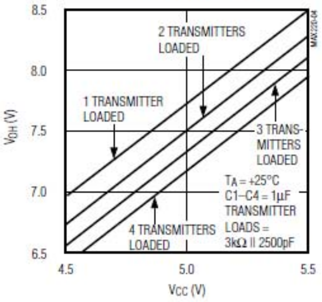
(MAX223/230/232/234/236/237/238/240/241, V_{CC} = +5V ±10; MAX233/MAX235, V_{CC} = 5V ±5%, C1–C4 = 1.0µF; MAX231/MAX239, V_{CC} = 5V ±10%; V+ = 7.5V to 13.2V; T_A = T_{MIN} to T_{MAX}; unless otherwise noted.)

PARAMETER	CONDITIONS			MIN	TYP	MAX	UNITS
RS-232 Input Threshold Low	T_A = +25°C, V_{CC} = 5V	Normal operation $\overline{SHDN}$ = 5V (MAX223) SHDN = 0V (MAX235/236/240/241)		0.8	1.2		V
		Shutdown (MAX223) $\overline{SHDN}$ = 0V, EN = 5V ($R4_{IN}$, $R5_{IN}$)		0.6	1.5		
RS-232 Input Threshold High	T_A = +25°C, V_{CC} = 5V	Normal operation $\overline{SHDN}$ = 5V (MAX223) SHDN = 0V (MAX235/236/240/241)			1.7	2.4	V
		Shutdown (MAX223) $\overline{SHDN}$ = 0V, EN = 5V ($R4_{IN}$, $R5_{IN}$)			1.5	2.4	
RS-232 Input Hysteresis	V_{CC} = 5V, no hysteresis in shutdown			0.2	0.5	1.0	V
RS-232 Input Resistance	T_A = +25°C, V_{CC} = 5V			3	5	7	kΩ
TTL/CMOS Output Voltage Low	I_{OUT} = 1.6mA (MAX231/232/233, I_{OUT} = 3.2mA)					0.4	V
TTL/CMOS Output Voltage High	I_{OUT} = -1mA			3.5	V_{CC} - 0.4		V
TTL/CMOS Output Leakage Current	0V ≤ R_{OUT} ≤ V_{CC}; EN = 0V (MAX223); $\overline{EN}$ = V_{CC} (MAX235–241)				0.05	±10	µA
Receiver Output Enable Time	Normal operation	MAX223			600		ns
		MAX235/236/239/240/241			400		
Receiver Output Disable Time	Normal operation	MAX223			900		ns
		MAX235/236/239/240/241			250		
Propagation Delay	RS-232 IN to TTL/CMOS OUT, C_L = 150pF	Normal operation			0.5	10	µs
		$\overline{SHDN}$ = 0V (MAX223)	t_{PHLS}		4	40	
			t_{PLHS}		6	40	
Transition Region Slew Rate	MAX223/MAX230/MAX234–241, T_A = +25°C, V_{CC} = 5V, R_L = 3kΩ to 7kΩ, C_L = 50pF to 2500pF, measured from +3V to -3V or -3V to +3V			3	5.1	30	V/µs
	MAX231/MAX232/MAX233, T_A = +25°C, V_{CC} = 5V, R_L = 3kΩ to 7kΩ, C_L = 50pF to 2500pF, measured from +3V to -3V or -3V to +3V				4	30	
Transmitter Output Resistance	V_{CC} = V+ = V- = 0V, V_{OUT} = ±2V			300			Ω
Transmitter Output Short-Circuit Current					±10		mA

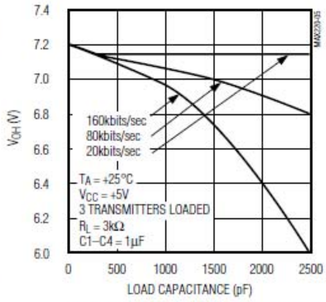
Typical Operating Characteristics

MAX223/MAX230–MAX241

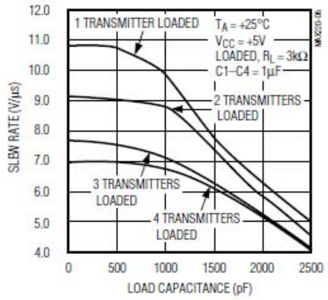
TRANSMITTER OUTPUT VOLTAGE (V_{OH}) vs. V_{CC}



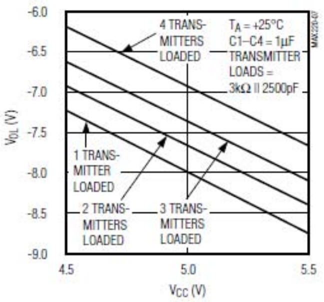
TRANSMITTER OUTPUT VOLTAGE (V_{OH}) vs. LOAD CAPACITANCE AT DIFFERENT DATA RATES



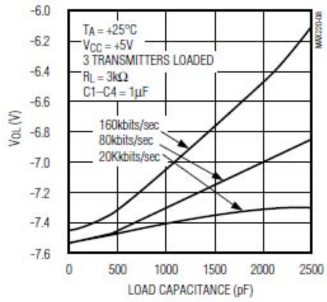
TRANSMITTER SLEW RATE vs. LOAD CAPACITANCE



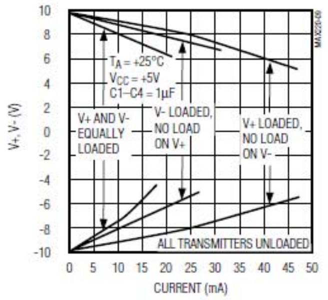
TRANSMITTER OUTPUT VOLTAGE (V_{OL}) vs. V_{CC}



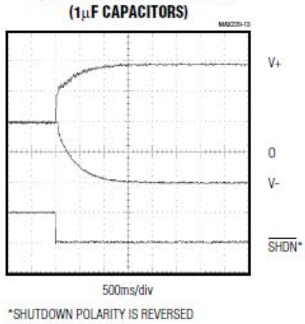
TRANSMITTER OUTPUT VOLTAGE (V_{OL}) vs. LOAD CAPACITANCE AT DIFFERENT DATA RATES



TRANSMITTER OUTPUT VOLTAGE (V+, V-) vs. LOAD CURRENT



V+, V- WHEN EXITING SHUTDOWN (1µF CAPACITORS)



*SHUTDOWN POLARITY IS REVERSED FOR NON MAX241 PARTS

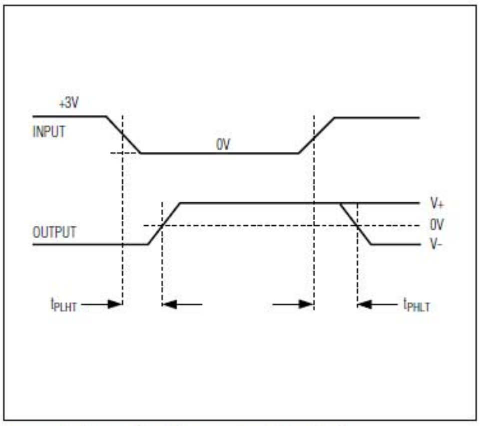


Figure 1. Transmitter Propagation-Delay Timing

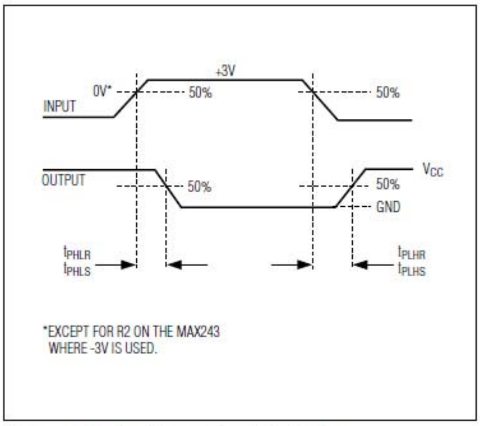


Figure 2. Receiver Propagation-Delay Timing

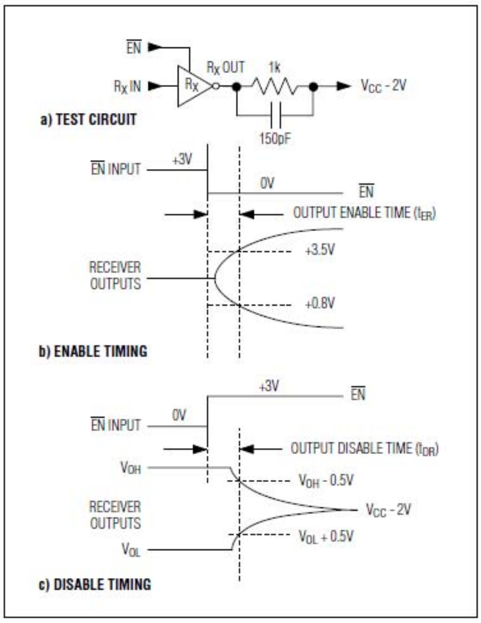


Figure 3. Receiver-Output Enable and Disable Timing

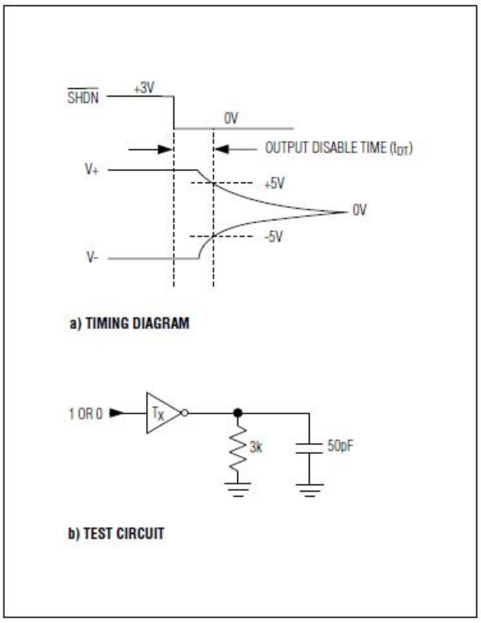


Figure 4. Transmitter-Output Disable Timing

Detailed Description

The MAX220–MAX249 contain four sections: dual charge-pump DC-DC voltage converters, RS-232 drivers, RS-232 receivers, and receiver and transmitter enable control inputs.

Dual Charge-Pump Voltage Converter

The MAX220–MAX249 have two internal charge-pumps that convert +5V to ±10V (unloaded) for RS-232 driver operation. The first converter uses capacitor C1 to double the +5V input to +10V on C3 at the V+ output. The second converter uses capacitor C2 to invert +10V to -10V on C4 at the V- output.

A small amount of power may be drawn from the +10V (V+) and -10V (V-) outputs to power external circuitry (see the *Typical Operating Characteristics* section), except on the MAX225 and MAX245–MAX247, where these pins are not available. V+ and V- are not regulated, so the output voltage drops with increasing load current. Do not load V+ and V- to a point that violates the minimum ±5V EIA/TIA-232E driver output voltage when sourcing current from V+ and V- to external circuitry.

When using the shutdown feature in the MAX222, MAX225, MAX230, MAX235, MAX236, MAX240, MAX241, and MAX245–MAX249, avoid using V+ and V- to power external circuitry. When these parts are shut down, V- falls to 0V, and V+ falls to +5V. For applications where a +10V external supply is applied to the V+ pin (instead of using the internal charge pump to generate +10V), the C1 capacitor must not be installed and the $\overline{SHDN}$ pin must be tied to V_{CC}. This is because V+ is internally connected to V_{CC} in shutdown mode.

RS-232 Drivers

The typical driver output voltage swing is ±8V when loaded with a nominal 5kΩ RS-232 receiver and V_{CC} = +5V. Output swing is guaranteed to meet the EIA/TIA-232E and V.28 specification, which calls for ±5V minimum driver output levels under worst-case conditions. These include a minimum 3kΩ load, V_{CC} = +4.5V, and maximum operating temperature. Unloaded driver output voltage ranges from (V+ -1.3V) to (V- +0.5V).

Input thresholds are both TTL and CMOS compatible. The inputs of unused drivers can be left unconnected since 400kΩ input pull-up resistors to V_{CC} are built in (except for the MAX220). The pull-up resistors force the outputs of unused drivers low because all drivers invert. The internal input pull-up resistors typically source 12µA, except in shutdown mode where the pull-ups are disabled. Driver outputs turn off and enter a high-impedance state—where leakage current is typically microamperes (maximum 25µA)—when in shutdown mode, in three-state mode, or when device power is removed. Outputs can be driven to ±15V. The power-supply current typically drops to 8µA in shutdown mode. The MAX220 does not have pull-up resistors to force the ouputs of the unused drivers low. Connect unused inputs to GND or V_{CC}.

The MAX239 has a receiver three-state control line, and the MAX223, MAX225, MAX235, MAX236, MAX240, and MAX241 have both a receiver three-state control line and a low-power shutdown control. Table 2 shows the effects of the shutdown control and receiver three-state control on the receiver outputs.

The receiver TTL/CMOS outputs are in a high-impedance, three-state mode whenever the three-state enable line is high (for the MAX225/MAX235/MAX236/MAX239–MAX241), and are also high-impedance whenever the shutdown control line is high.

When in low-power shutdown mode, the driver outputs are turned off and their leakage current is less than 1µA with the driver output pulled to ground. The driver output leakage remains less than 1µA, even if the transmitter output is backdriven between 0V and (V_{CC} + 6V). Below -0.5V, the transmitter is diode clamped to ground with 1kΩ series impedance. The transmitter is also zener clamped to approximately V_{CC} + 6V, with a series impedance of 1kΩ.

The driver output slew rate is limited to less than 30V/µs as required by the EIA/TIA-232E and V.28 specifications. Typical slew rates are 24V/µs unloaded and 10V/µs loaded with 3Ω and 2500pF.

RS-232 Receivers

EIA/TIA-232E and V.28 specifications define a voltage level greater than 3V as a logic 0, so all receivers invert. Input thresholds are set at 0.8V and 2.4V, so receivers respond to TTL level inputs as well as EIA/TIA-232E and V.28 levels.

The receiver inputs withstand an input overvoltage up to ±25V and provide input terminating resistors with

Table 2. Three-State Control of Receivers

PART	SHDN	$\overline{SHDN}$	EN	$\overline{EN(R)}$	RECEIVERS
MAX223	—	Low High High	X Low High	—	High Impedance Active High Impedance
MAX225	—	—	—	Low High	High Impedance Active
MAX235 MAX236 MAX240	Low Low High	—	—	Low High X	High Impedance Active High Impedance

nominal 5kΩ values. The receivers implement Type 1 interpretation of the fault conditions of V.28 and EIA/TIA-232E.

The receiver input hysteresis is typically 0.5V with a guaranteed minimum of 0.2V. This produces clear output transitions with slow-moving input signals, even with moderate amounts of noise and ringing. The receiver propagation delay is typically 600ns and is independent of input swing direction.

Low-Power Receive Mode

The low-power receive-mode feature of the MAX223, MAX242, and MAX245–MAX249 puts the IC into shutdown mode but still allows it to receive information. This is important for applications where systems are periodically awakened to look for activity. Using low-power receive mode, the system can still receive a signal that will activate it on command and prepare it for communication at faster data rates. This operation conserves system power.

Negative Threshold—MAX243

The MAX243 is pin compatible with the MAX232A, differing only in that RS-232 cable fault protection is removed on one of the two receiver inputs. This means that control lines such as CTS and RTS can either be driven or left floating without interrupting communication. Different cables are not needed to interface with different pieces of equipment.

The input threshold of the receiver without cable fault protection is -0.8V rather than +1.4V. Its output goes positive only if the input is connected to a control line that is actively driven negative. If not driven, it defaults to the 0 or "OK to send" state. Normally, the MAX243's other receiver (+1.4V threshold) is used for the data line (TD or RD), while the negative threshold receiver is connected to the control line (DTR, DTS, CTS, RTS, etc.).

Other members of the RS-232 family implement the optional cable fault protection as specified by EIA/TIA-232E specifications. This means a receiver output goes high whenever its input is driven negative, left floating, or shorted to ground. The high output tells the serial communications IC to stop sending data. To avoid this, the control lines must either be driven or connected with jumpers to an appropriate positive voltage level.

Shutdown—MAX222–MAX242

On the MAX222, MAX235, MAX236, MAX240, and MAX241, all receivers are disabled during shutdown. On the MAX223 and MAX242, two receivers continue to operate in a reduced power mode when the chip is in shutdown. Under these conditions, the propagation delay increases to about 2.5μs for a high-to-low input transition. When in shutdown, the receiver acts as a CMOS inverter with no hysteresis. The MAX223 and MAX242 also have a receiver output enable input ($\overline{EN}$ for the MAX242 and EN for the MAX223) that allows receiver output control independent of $\overline{SHDN}$ (SHDN for MAX241). With all other devices, $\overline{SHDN}$ (SHDN for MAX241) also disables the receiver outputs.

The MAX225 provides five transmitters and five receivers, while the MAX245 provides ten receivers and eight transmitters. Both devices have separate receiver and transmitter-enable controls. The charge pumps turn off and the devices shut down when a logic high is applied to the ENT input. In this state, the supply current drops to less than 25μA and the receivers continue to operate in a low-power receive mode. Driver outputs enter a high-impedance state (three-state mode). On the MAX225, all five receivers are controlled by the $\overline{ENR}$ input. On the MAX245, eight of the receiver outputs are controlled by the $\overline{ENR}$ input, while the remaining two receivers (RA5 and RB5) are always active. RA1–RA4 and RB1–RB4 are put in a three-state mode when $\overline{ENR}$ is a logic high.

Receiver and Transmitter Enable Control Inputs

The MAX225 and MAX245–MAX249 feature transmitter and receiver enable controls.

The receivers have three modes of operation: full-speed receive (normal active), three-state (disabled), and low-power receive (enabled receivers continue to function at lower data rates). The receiver enable inputs control the full-speed receive and three-state modes. The transmitters have two modes of operation: full-speed transmit (normal active) and three-state (disabled). The transmitter enable inputs also control the shutdown mode. The device enters shutdown mode when all transmitters are disabled. Enabled receivers function in the low-power receive mode when in shutdown.

+5V-Powered, Multichannel RS-232 Drivers/Receivers

Tables 1a–1d define the control states. The MAX244 has no control pins and is not included in these tables.

The MAX246 has ten receivers and eight drivers with two control pins, each controlling one side of the device. A logic high at the A-side control input ($\overline{ENA}$) causes the four A-side receivers and drivers to go into a three-state mode. Similarly, the B-side control input ($\overline{ENB}$) causes the four B-side drivers and receivers to go into a three-state mode. As in the MAX245, one A-side and one B-side receiver (RA5 and RB5) remain active at all times. The entire device is put into shutdown mode when both the A and B sides are disabled ($\overline{ENA}$ = $\overline{ENB}$ = +5V).

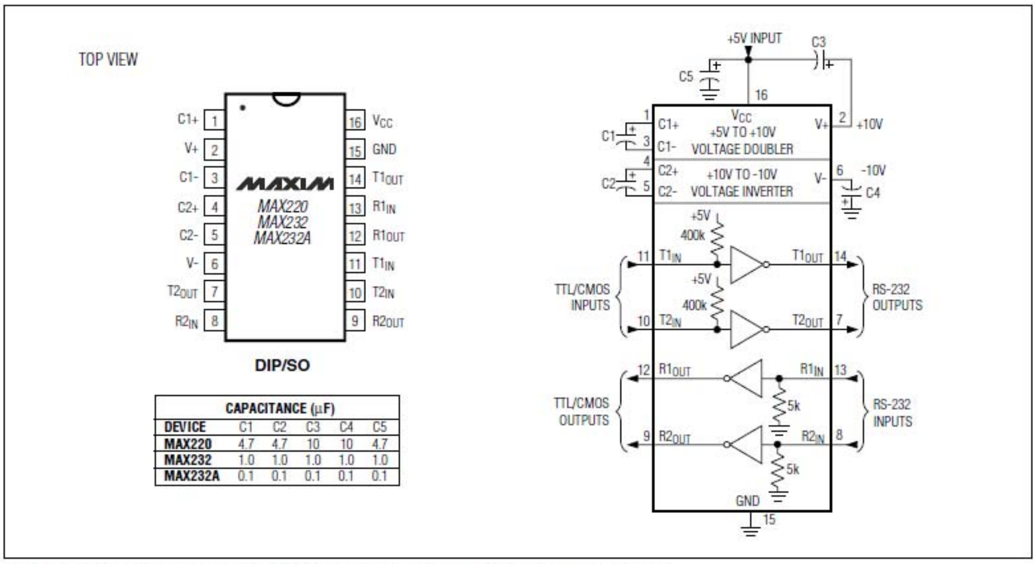
The MAX247 provides nine receivers and eight drivers with four control pins. The $\overline{ENRA}$ and $\overline{ENRB}$ receiver enable inputs each control four receiver outputs. The $\overline{ENTA}$ and $\overline{ENTB}$ transmitter enable inputs each control four drivers. The ninth receiver (RB5) is always active. The device enters shutdown mode with a logic high on both $\overline{ENTA}$ and $\overline{ENTB}$.

The MAX248 provides eight receivers and eight drivers with four control pins. The $\overline{ENRA}$ and $\overline{ENRB}$ receiver enable inputs each control four receiver outputs. The $\overline{ENTA}$ and $\overline{ENTB}$ transmitter enable inputs control four drivers each. This part does not have an always-active receiver. The device enters shutdown mode and transmitters go into a three-state mode with a logic high on both $\overline{ENTA}$ and $\overline{ENTB}$.

The MAX249 provides ten receivers and six drivers with four control pins. The $\overline{ENRA}$ and $\overline{ENRB}$ receiver enable inputs each control five receiver outputs. The $\overline{ENTA}$ and $\overline{ENTB}$ transmitter enable inputs control three drivers each. There is no always-active receiver. The device enters shutdown mode and transmitters go into a three-state mode with a logic high on both $\overline{ENTA}$ and $\overline{ENTB}$. In shutdown mode, active receivers operate in a low-power receive mode at data rates up to 20kbits/sec.

Applications Information

Figures 5 through 25 show pin configurations and typical operating circuits. In applications that are sensitive to power-supply noise, V_{CC} should be decoupled to ground with a capacitor of the same value as C1 and C2 connected as close as possible to the device.



CAPACITANCE (μF)					
DEVICE	C1	C2	C3	C4	C5
MAX220	4.7	4.7	10	10	4.7
MAX232	1.0	1.0	1.0	1.0	1.0
MAX232A	0.1	0.1	0.1	0.1	0.1

Figure 5. MAX220/MAX232/MAX232A Pin Configuration and Typical Operating Circuit

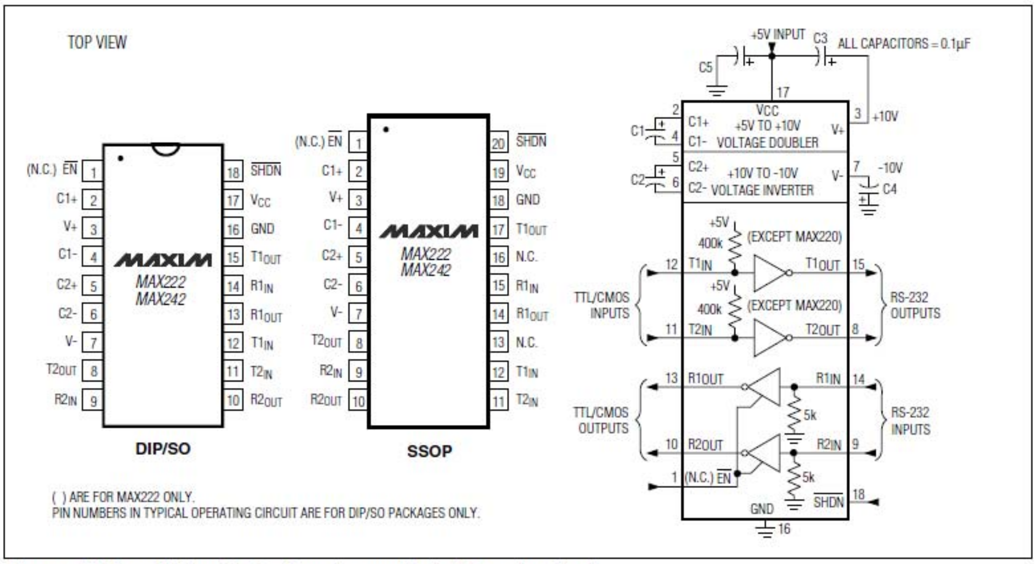


Figure 6. MAX222/MAX242 Pin Configurations and Typical Operating Circuit

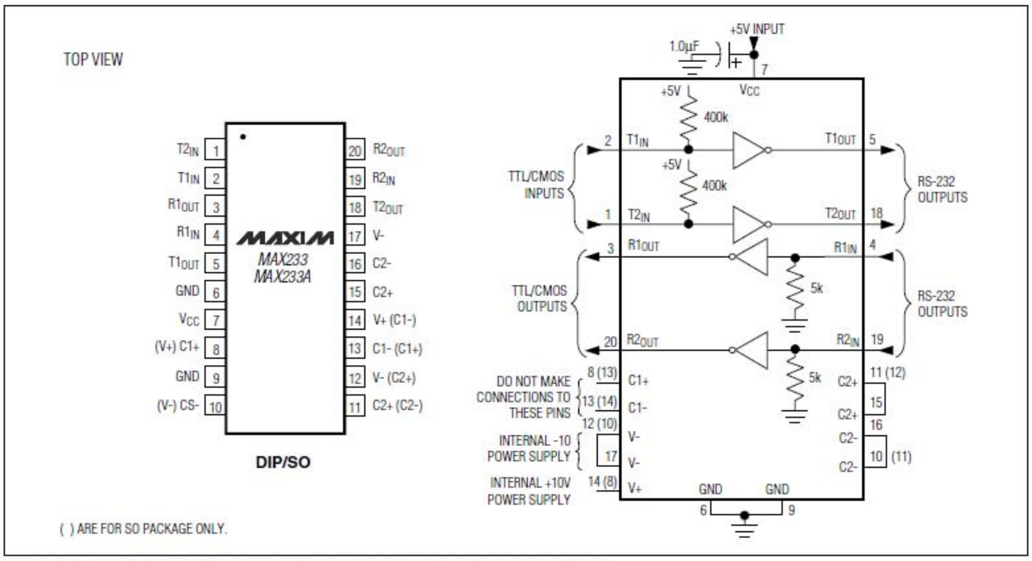


Figure 11. MAX233/MAX233A Pin Configuration and Typical Operating Circuit